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COST EFFECTIVENESS STUDY OF WEATHER PROTECTION FOR SHIPBUILDING OPERATIONS

VOLUME II

TODD SHIPYARDS CORPORATION

PREPARED FOR

MARITIME ADMINISTRATION

APRIL 1974

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This report contains data on how weather factors impact adversely on the shipbuilding process. It is comprehensive, not intended for the casual reader, and useful for the purpose of quantifying losses due to weather. It can serve management to determine how much money should be invested in weather protection devices.

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CONTENTS - VOLUME II -APPENDIX

APPENDIX A

THE PRODUCTIVITY MODEL

DESCRIPTION OF THE PRODUCTIVITY MODEL

After a critical review of our notes from the shipyard interviews, the questionnaires, other data, and reports, we constructed Table A-1 which represents the productivity for the various crafts under selected weather categories and working locations. The effect of temperature on productivity in Table A-1 is based on Figure A-l, which is adapted from Figure C-1, Appendix C. Productivity values for some crafts varied from the norm according to the relative adverse effect of the weather category on that craft as indicated by the nature of the work. The values shown in Table A-1 assume no special Weather protection aside from normal clothing to fit the conditions. In-ship workers are assumed to be protected from wind and direct precipitation by ship structures. A special algorithn (Exhibit A) is applied to cover pass-out conditions for precipitation (or for relative humidity for painters and blasters). Exhibits B, C, and D provide explanations of our assumptions, special conditions, and penalties used to develop Table A-1.

Effective temperature (outside) is defined as the dry bulb temperature minus the wind speed in mph. This is a reasonable approximation of the wind chill factor over normal temperature ranges. Me applfed the wind chill correction to dry bulb temperatures below 80°F. Above 80°F and within the ship, the effective temperature is the dry bulb temperature.

This model is applied to combinations of weather conditions with temperature by multiplying the probabilities of each other weather occurrence with its associated productivity. Under a set of combined weather conditions, the productivity in each temperature range Is the product of these separate productivities. The average annual productivity is the total of the separate productivities within each temperature range. with this model, We compute the average annual productivity for each craft and shift and for the entire standard shipyard for each shipyard location. The sample calculation which follows describes this procedure. A listing of the computer program to perform these calculations is given in

TABLE A-1. Estimated Productivity (%) of Shipyard Workers Under Various Weather Conditions

	EFFECTIVE TEMPERATURE (°F)								WIND (MPH)			PRECIPITATION (INCHES)				
CRAFTS	<5	5-19	20-29	30-39	40-79	80-89	90-99	100+	<12	13-24	25+	None	Trace	.01	.02-.09	.1+
OUTSIDE																
Painters	30	56	75	92	100	84	48	15	100	70	0	100	*	0	0	0
Welders	25	51	70	92	100	79	48	15	100	80	10	100	100	80	0	0
Riggers	25	55	75	92	100	84	53	20	100	90	15	100	100	95	85	40
Fitters	25	51	70	92	100	84	53	20	100	90	20	100	100	95	85	40
Others	30	56	75	92	100	84	53	20	100	95	40	100	100	95	90	50
IN SHIP (Effective Temperature = Dry Bulb Temperature)																
Painters	0	0	0	70	100	79	48	15	100	100	80	100	*	*	*	*
Welders	30	56	75	100	100	74	43	10	100	100	80	100	100	100	95	80
Riggers	30	56	75	92	100	79	48	15	100	100	80	100	100	100	95	80
Fitters	30	56	75	92	100	79	40	15	100	100	80	100	100	100	95	80
Others	30	55	75	92	100	79	40	15	100	100	80	100	100	100	95	80

* Relative humidity is assumed to be the dominant factor affecting the productivity of painters and blasters

TABLE A-1 (continued). Estimated Productivity (%) of Shipyard Workers Under Various Weather Conditions

CRAFTS	RELATIVE HUMIDITY <90	RELATIVE HUMIDITY 90-100	FOG Visibility <1/16 Mile	SHADE CLOUD COVER INDEX 9 a.m. - 6 p.m. <3 Temp. <80° F	SHADE CLOUD COVER INDEX 9 a.m. - 6 p.m. 8-10 Temp. <80° F
OUTSIDE					
Painters	100	0	**	70	100
Welders	100	100	**	70	100
Riggers	100	100	50-Day 30-Night	70	100
Fitters	100	100	50-Day 30-Night	70	100
Others	100	100	**	70	100
IN SHIP (Effective Temperature = Dry Bulb Temperature)					
Painters	100	0	Same as for	95	100
Welders	100	100	outside crafts	95	100
Riggers	100	100	*	95	100
Fitters	100	100	*	95	100
Others	100	100	*	95	100

** Not Directly Applicable

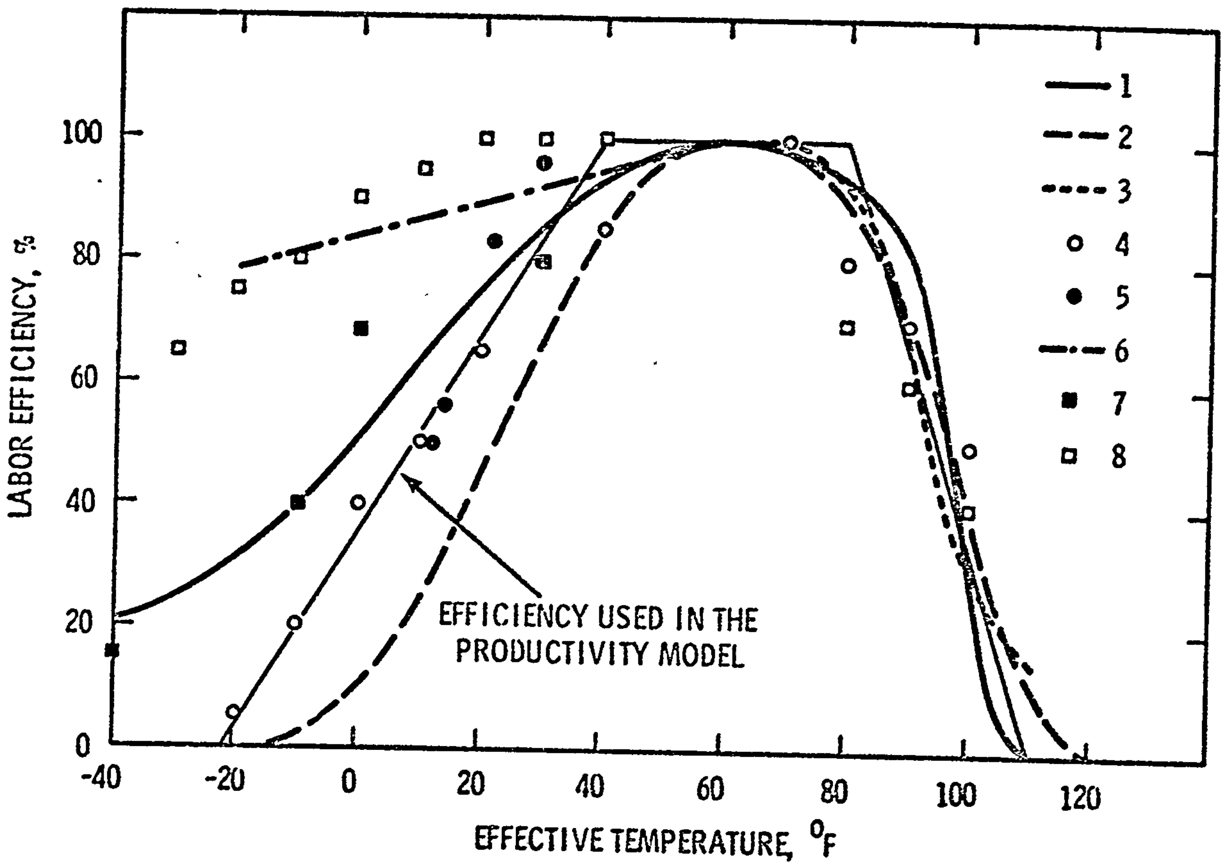

FIGURE A-1. Outdoor Worker Efficiency

LEGEND

1. Doyle, "Controlling Climate Effects", Tool Engr., 1955 (efficiency curve prepared under condition of little or no wind.
2. General Dynamics, Quincy (DX Study).
3. ASHVE Guide and Data Book (men at work 90,000 ft-lb of work per hour).
4. Constructor, May 1972 (welders, pipefitters, carpenters, electricians).
5. Unidentified shipyard estimate (converted from equivalent temperature to effective temperature).
6. Bechtel construction project in Canada (winter) - (converted from wind chill temperature and corrected to 100% efiiciency at 60"F).
7, ASHVE Guide and Data Book (Armstrong's data for line-maintenance job).
8. Constructor, May 1972 (laborers, ironworkers, operating engineers).

Appendix L. Improvements in the average productivity for the entire shipyard provide the basis for assessing the cost-effectiveness of various weather protective facilities.

Sample Calculation

Assume: A welder is working outside on day shift in 30 to 39°F effective temperature, (already corrected for the wind chill effect). The frequency of wind at this shipyard is 80% less than 12 mph, 15% between 13 to 24 mph, and 5% above 25mph. The frequency of precipitation is 85% none or trace, 10% at 0.01 in./hr, 3% from 0.02 to 0.09 in./hr, and 2% at 0.l+ in./hr. The welders average productivity in wind alone would be, using these frequencies and the productivity values in Table A-1:

0.80 x 1.00 + 0.15 x 0.80 + 0.5 x O. = 0.92 0r 92%

The welders average productivity affected by precipitation alone would be

0.85 X 1.00 + 0.10 X 0.80 + 0.03 x O. + 0.2 x 0. = 0.93 0r 93%

The welders average productivity for the 30 to 39°F effective temperature range would be the product of the productivities for temperature, wind, and precipitation, or

0.92 x 0.92 x 0.93 = 0.7870r 79%

If the 30 to 39°F effective temperature occurred 10% of the time for the shipyard location, the average annual outside productivity of welders in this temperature range would be O.10 x 0.79 or 0.079. The total annual productility would be the sum of the productivities for each effective temperature category. This type of calculation is repeated for each shift, each work location, and each craft.

The total shipyard productivity is the sum of craft, shift, and location productivities weighted by the number of craftsmen involved. The total shipyard productivity (when subtracted from unity and multiplied by the annual hours worked) indicates the total manhours of productivity lost because of adverse weather.

Since fog is not assumed to affect welders and since shade is assumed to be effective only at temperatures above 80°F, these conditions were not included in this calculation. Fog and shade, when included, are treated similarly to wind and precipitation.

ABSENTEEISM AND TURNOVER

Although the shipyards attributed some absenteeism and turnover to the weather, these were not believed to be major cost factors. Comnents ran from "less than 5% of the absenteeism is caused by weather" to "its just as well they do not show up in bad weather, we would have to send them back home anyway."

On turnover, it was felt by some that poor working conditions caused by bad weather led employees to take other work when available. One shipyard foreman remarked that inside work was preferred by his crew even in good weather.

Since it was not possible to establish the rate or cost of either absenteeism or turnover to weather, these factors were omitted from our model.

An Assessment of Potential Bias in the Model

Our model is intended to provide a simplified approximation of the real situation. Since the real situation is too complex and too little understood to permit an economical exhaustive analysis, several simplifying assumptions were made and several factors were omitted from the model. These assumptions and omitted factors were examined in order to estimate, at least qualitatively their overall affect on our reported results. These factors are listed below according to whether they would tend to increase or decrease the benefits resulting from increased weather protection in the shipyards. On balance, we believe that the tendency toward increased benefits would far outweigh the tendency towards decreased benefits, and therefore, our results probably understated the potential benefits of increased weather protection.

Reasons Why Benefits May Exceed Those Calculated

1. We purposely tried to avoid overestimating productivity losses.
2. We did not include costs attributable to absenteeism and turnover.
3. He did not include potential benefits that might result from the ability to install more automated equipment through covering.
4. We did not include benefits from improved lighting.
5. He did not include benefits resulting from improved accident experience and the reduced potential for work stoppage for safety reasons under adverse conditions.
6. We did not include savings immaterial losses.
7. We did not include potential benefits from reduced maintenance on equipnent, and lower capital costs of equipment purchased for inside use which does not have to be weathertight, hence, costs less, and is usually less expensive to install than outside in the weather.
8. We did not include losses resulting from extreme or extended adverse weather conditions. These would tend to be ameliorated with better weather protection.
9. The impact of snow and snow cover on lost production and time spent searching for and/or reproducing material lost in the snow was not included.
10. The savings in eliminating existing space heating and cooling costs were not included.
11. Higher and more consistent quality may result.
12. Smaller structures might be more cost-effective than a complete covering of an area, since more workers may be covered per unit area.
13. Hater and snow removal costs were not included.

Reasons Why Benefits May Be Less Than Those Calculated

1. Real conditions may not resemble the model shipyard.
   a worker distribution may be different
   b) the work load may be too variable
   c) fixed and variable expenses may be different

2. *Covering may impede work more than estimated.*

3. *Workers may acclimatize to a greater extent than assumed; thus, productivity saving may be overstated.*

4. *Covering costs may be greater than estimated.*

5. *Other factors may have a much greater effect on productivity and overshadow the effects of weather.*

6. *Extreme weather tends to occur less frequently than more moderate weather. Within each weather class, weather occurrences tend to be biased toward the moderate. For instance, the temperature is more frequently between 35°F to 39°F than 30°F to 34°F. In estimating the productivity of a weather class at the midpoint, we may have introduced a slight bias toward lower productivity.*

The Effects of Meather on Productivity as Determined by the Modei

After applying the productivity model to the weather conditions near each shipyard location, the results were analyzed to determine the average annual productivity, both outside and in-ship, for each craft and shipyard location (Table A-2). The results were also analyzed to determine the effect of providing protection against specific weather conditions (Tables A-3 through A-7). The factors in these tables show the estimated productivity gain for each outside craft at each shipyard location of providing each type of weather protection. For example, referring to Table A-3, providing wind protection at San Diego would increase the productivity of outside painters by 1.034 or 3.4% (1.034 - 1.000). Tables A-4 through A-7 show the relative productivity increases for the other outside crafts. These factors should be generally applicable to productivity calculations for other weather protective devices, as described in the next section.

APPLICATION OF PRODUCTIVITY MODEL TO A SPECIFIC SHIPYARD

The productivity model may be applied to a specific weather protection facility and shipyard through the use of the factors shown in Tables A-3 through A-7. These factors represent the potential productivity increase

TABLE A-2. Average Annual Productivity by Craft and Work Location

Location	Painters Outside	Painters Inship	Welders Outside	Welders Inship	Rigger Outide	Rigger Inship	Fitters Outside	Fitters Inship	Others Outside	Others Inship
Baltimore	0.581	0.733	0.721	0.923	0.786	0.908	0.775	0.912	0.812	0.916
New Orleans	0.703	0.799	0.795	0.904	0.854	0.910	0.852	0.910	0.877	0.915
Portland, Oregon	0.706	0.802	0.805	0.967	0.875	0.953	0.869	0.955	0.895	0.960
Norfolk, VA	0.656	0.800	0.759	0.934	0.812	0.911	0.805	0.913	0.850	0.932
Portland, Maine	0.461	0.581	0.685	0.904	0.751	0.883	0.737	0.886	0.779	0.892
New York	0.562	0.748	0.705	0.948	0.777	0.929	0.766	0.932	0.811	0.937
Houston	0.620	0.772	0.732	0.887	0.800	0.894	0.798	0.895	0.833	0.899
Seattle	0.590	0.737	0.749	0.970	0.823	0.949	0.814	0.951	0.857	0.961
San Diego	0.930	0.963	0.956	0.989	0.970	0.986	0.970	0.986	0.980	0.991
Mobile	0.653	0.770	0.779	0.913	0.837	0.915	0.835	0.916	0.862	0.920
Boston	0.499	0.711	0.637	0.924	0.717	0.906	0.706	0.909	0.759	0.914
Los Angeles	0.881	0.941	0.928	0.986	0.951	0.982	0.952	0.982	0.967	0.987
Philadelphia	0.610	0.746	0.744	0.930	0.807	0.913	0.796	0.917	0.831	0.921
Galveston	0.633	0.788	0.745	0.898	0.814	0.910	0.812	0.910	0.844	0.913

NOTE: The above table covers only outside and in-ship locations. Crafts located in shops are unaffected by weather and are assumed to have a productivity of 1.0 (100%).

TABLE A-3. Estimated Productivity Gain for Painters Normally Assigned to Outsic
When Protection Is Prcvided for Each Adverse Weather Condition

	Weather Protection Provided				
Location	Shade	Rain Protection	Dehumidifiers	Wind Protection	Coolinc
San Diego	1.004	1.000	1.031	1.034	1.004
Mobile	1.026	1.000	1.196	1.162	1.054
Boston	1.006	1.000	1.135	1.439	1.016
Los Angeles	1.003	1.000	1.054	1.067	1.003
Philadelphia	1.010	1.000	1.117	1.223	1.025
New Orleans	1.011	1.000	1.155	1.142	1.061
Norfolk	1.014	1.000	1.120	1.216	1.032
Portland, Maine	1.004	1.000	1.263	1.262	1.009
New York	1.007	1.000	1.147	1.336	1.012
Houston	1.029	1.000	1.169	1.242	1.071
Seattle	1.002	1.000	1.262	1.255	1.003
Portland, Oregon	1.003	1.000	1.167	1.139	1.008
Baltimore	1.015	1.000	1.137	1.262	1.033
Galveston	1.036	1.000	1.163	1.236	1.057

NOTE: For painters, productivity gains for rain protection are included in the gains dehumidifiers. It was assumed that rain protection alone gave no productivity because relative humidity during rain was above 90%, a stop work condition for

TABLE A-4. Estimated Productivity Gain for Riggers Normally Assigned to Outside Work When Protection Is Provided for Each Adverse Weather Condition

	Weather Protection Provided					
Location	Shade	Rain Protection	Dehumidifiers	Wind Protection	Cooling	Heating
San Diego	1.003	1.005	1.000	1.012	1.004	1.007
Mobile	1.024	1.021	1.000	1.021	1.078	1.032
Boston	1.007	1.024	1.000	1.266	1.014	1.054
Los Angeles	1.004	1.008	1.000	1.028	1.004	1.007
Philadelphia	1.010	1.018	1.000	1.126	1.021	1.048
New Orleans	1.011	1.021	1.000	1.062	1.056	1.012
Norfolk	1.014	1.021	1.000	1.113	1.028	1.040
Portland, Maine	1.004	1.024	1.000	1.169	1.007	1.100
New York	1.006	1.021	1.000	1.198	1.025	1.020
Houston	1.028	1.017	1.000	1.109	1.065	1.012
Seattle	1.001	1.023	1.000	1.150	1.003	1.029
Portland, Oregon	1.002	1.026	1.000	1.081	1.007	1.021
Baltimore	1.013	1.019	1.000	1.151	1.027	1.043
Galveston	1.036	1.012	1.000	1.106	1.057	1.002

NOTE: No productivity allowance was made for humidity control for crafts other than painters. It was assumed that the productivity estimates for each temperature range included the average effects of humidity.

TABLE A-5. Estimated Productivity Gain for Fitters Normally Assigned to Outside Work When Protection Is Provided for Each Adverse Weather Condition

Location	Weather Protection Provided: Shade	Rain Protection	Dehumidifiers	Wind Protection	Cooling	Heating
San Diego	1.003	1.005	1.000	1.012	1.004	1.007
Mobile	1.024	1.021	1.000	1.080	1.051	1.009
Boston	1.006	1.025	1.000	1.278	1.013	1.061
Los Angeles	1.003	1.008	1.000	1.027	1.003	1.009
Philadelphia	1.010	1.019	1.000	1.137	1.021	1.051
New Orleans	1.012	1.020	1.000	1.065	1.056	1.011
Norfolk	1.014	1.021	1.000	1.120	1.029	1.041
Portland, Maine	1.004	1.023	1.000	1.179	1.007	1.113
New York	1.009	1.019	1.000	1.210	1.025	1.024
Houston	1.029	1.017	1.000	1.112	1.066	1.010
Seattle	1.001	1.023	1.000	1.162	1.003	1.029
Portland, Oregon	1.002	1.026	1.000	1.087	1.008	1.022
Baltimore	1.013	1.019	1.000	1.193	1.027	1.047
Galveston	1.036	1.013	1.000	1.107	1.057	1.003

NOTE: No productivity allowance was made for humidity control for crafts other than painters. It was assumed that the productivity estimates for each temperature range included the average effects of humidity.

TABLE A-6. Estimated Productivity Gain for Other Crafts Normally Assigned to Outside Work When Protection Is Provided for Each Adverse Weather Condition

	Weather Protection Provided					
Location	Shade	Rain Protection	Dehumidifiers	Wind Protection	Cooling	Heating
San Diego	1.004	1.004	1.000	1.008	1.005	1.000
Mobile	1.024	1.018	1.000	1.055	1.051	1.004
Boston	1.005	1.020	1.000	1.207	1.013	1.051
Los Angeles	1.004	1.007	1.000	1.018	1.004	1.001
Philadelphia	1.010	1.015	1.000	1.102	1.020	1.044
New Orleans	1.011	1.017	1.000	1.042	1.056	1.008
Norfolk	1.014	1.017	1.000	1.088	1.029	1.019
Portland, Maine	1.004	1.019	1.000	1.140	1.006	1.094
New York	1.007	1.017	1.000	1.157	1.022	1.018
Houston	1.028	1.015	1.000	1.073	1.065	1.007
Seattle	1.001	1.020	1.000	1.120	1.003	1.017
Portland, Oregon	1.002	1.022	1.000	1.066	1.008	1.037
Baltimore	1.012	1.017	1.000	1.123	1.027	1.038
Galveston	1.036	1.011	1.000	1.069	1.058	1.000

NOTE: No productivity allowance was made for humidity control for crafts other than painters. It was assumed that the productivity estimates for each temperature range included the average effects of humidity.

TABLE A-7. Estimated Productivity Gain for Welders Normally Assigned to Outside Work When Protection Is Provided for Each Adverse Weather Condition

Location	Shade	Rain Protection	Dehumidifiers	Wind Protection	Cooling	Heating
			Weather Protection Provided			
San Diego	1.004	1.013	1.000	1.023	1.005	1.000
Mobile	1.023	1.048	1.000	1.122	1.063	1.121
Boston	1.005	1.067	1.000	1.364	1.016	1.056
Los Angeles	1.003	1.019	1.000	1.047	1.005	1.002
Philadelphia	1.009	1.052	1.000	1.179	1.027	1.046
New Orleans	1.011	1.047	1.000	1.102	1.072	1.006
Norfolk	1.013	1.052	1.000	1.169	1.036	1.021
Portland, Maine	1.003	1.066	1.000	1.223	1.009	1.106
New York	1.006	1.058	1.000	1.276	1.014	1.030
Houston	1.027	1.040	1.000	1.173	1.082	1.008
Seattle	1.001	1.076	1.000	1.212	1.004	1.018
Portland, Oregon	1.002	1.074	1.000	1.113	1.010	1.027
Baltimore	1.012	1.052	1.000	1.209	1.033	1.043
Galveston	1.035	1.030	1.000	1.170	1.076	1.000

NOTE: No productivity allowance was made for humidity control for crafts other than painters. It was assumed that the productivity estimates for each temperature range included the average effects of humidity.

attributablee to each weather condition for each craft, work location, and shipbuilding region. An individual shipyard could estimate the productivity gain a weather protection facility at their shipyard using the following formula.

$$P_g = P_a \times P_b \times P_c \cdots \times P_n - 1$$

where

P_g = fraction productivity gain for each craft and location affected

P_a = fraction gain for that craft and location for a specific weather protection, e.g., wind

P_b = fraction gain for each craft, location, and second weather protection, e.g., shade

P_c = fraction gain for each craft, location, and third weather protection, e.g., rain

P_n = continue for each additional weather protection category

Then, taking the number of craft people protected by the facility

Annual $ saved each craft and location = P_g x effective annual wage expense for craft x number of craft people protected

Total $ saved $\sum$ $ saved for each craft and location.

For illustration, assme the weather protection facility is a completely enclosed, unheated and uncooled, building for 35 welders in Baltimore. The building provides shade and complete protection from rain and wind. 'The estimated productivity gain (using factors for Baltimore from Table A-7) would be

$$P_g = P_{shade} \times P_{rain} \times P_{wind} - 1$$

$$= 1.012 \times 1.052 \times 1.209 - 1$$

$$= 0.287 \ (28.7\%)$$

Assume the average annual expenditure per welder is $20,000.

Then, the annual dollar savings for increased productivity for this facility would be (for 35 welders)

0.287 X $20,000 X 35 = $200,000

In other words, $200,000 of additional work could be performed annually by these welders. A greater savings would result if overtime premiums were reduced, and an even greater savings would result if a greater shipbuilding capacity were achievable; i.e., to the extent that the welders were on the critical path. If other crafts were also protected from weather by this facility, the dollars saved would be added for each craft. The total dollars saved annually should be compared with the total annual dollar expenditure for each facility to determine the cost-effectiveness of the facility.

If this analysis appears cost-effective, the estimates of productivity which form the basis for the model (Table A-1) should be re-evaluated for the local situation and the analysis repeated, if lower productivity factors are indicated. Alternatively, new productivity estimates could be entered in the computer program data base, Appendix Land the program could be run to obtain' new productivity factors.

EXHIBIT A

ALGORITHM FOR PRECIPITATION COVERING PASS-OUT CORDITIONS AND TRANSFER OF WORKERS TO PROTECTED LOCATIONS

Workers will be passed out only for Precipitation rates greater than. .02"'/hr or, for painters and blasters only, for relative humidity occurrences greater than 90%. The occurrences of precipitation will be averaged over each shift in the following categories: .O1"/hr; .02" - .09"/hr; .1" Or greater/hr.

(1) All workers will work in .O1"/hr precipitation at the reduced productivity rate. No pass-outs.

(2) For the two precipitation categories of .02" and greater/hr, we will assume that 20% of the workers will be passed out sometime during the shift, and the remaining 80% will work the entire shift at the reduced productivity rate.

(a) We will assume that on the average the pass-outs will occur rather uniformly throughout the shift; that is:

(i) 1/4 of the time, the workers will be sent home at the beginning of the shift; work - 2 hours pay.

(ii) l/4 of the time, the workers will be sent home after 2 hours; 2 hours work - 4 hours pay.

(iii) l/4 of the time, the workers will be sent home after 4 hours; 4 hours work - 4 hours pay.

(iv) l/4 of the time, the workers will be sent home with 6 hours work and 6 hours pay.

As shown in Table A-8 this can be sumarized as 7.2 hours (90%) are paid, on the average, for 7.0 hours (87.5%) work for these occurrences. The productivity during the work periods is, of course, reduced according to Table A-1.

(b) In those cases where outside productivity would be zero, as for painters and welders, we will assume that 1 hour of each work day is lost transferring 80% of the workers to inside work. We will further assure the same 80% were transferred to inside work at the beginning of the shift in anticipation of precipitation. Table A-8 then becomes for these instances:

7.2 hours pay
.6 hours outside work - 100% productivity (average hours of outside work performed by the 20% of the workers before being passed out)
5.6 hours inside work - @ applicable productivity rate

TABLE A-8. Assumed Paid Time and Hours Worked When Precipitation Rate >.02"/Hr

Fraction of Time	Fraction of Workers	Hours Pay	Weighted Hours Pay	Hours Work	Weighted Hours Work
1/4	.2	2	.1	0	0
	.8	8	1.6	8	1.6
1/4	.2	4	.2	2	.1
	.8	8	1.6	8	1.6
1/4	.2	4	.2	4	.2
	.8	8	1.6	8	1.6
1/4	.2	6	.3	6	.3
	.8	8	1.6	8	1.6
			7.2		7.0

EXHIBIT B

EXPLANATIONS OF SPECIAL CONDITIONS AND PENALITIES MHICH APPLY TO THE PRODUCTIVITY TABLE A-1

(Comparisons are to all other crafts)

(1) Painters will work outside only when actual temperature is 35°F or above.

(2) Painters’ productivity was penalized additional 5% for temperatures over 90°F because some paints cannot be applied in this temperature range.

(3) Painters’ productivity in wind is penalized additionally because of high paint losses; i.e., more spraying is required to achieve same coating thickness.

(4) Painter will work outside only when the relative humidity is less than 90%. The effect of fog and other precipitation is included in the relative humidity affect.

(5) Welders and fitters are penalized 5% when effective temperature is below 29°F caused by more preheating time and the effect of cold steel on the welders comfort.

(6) Welders are penalized 5% when effective temperature exceeds 80″F for additional fatigues caused by heat radiation from hot steel.

(7) Riggers are penalized 5% at temperatures <5°F because of reduced service availability of cranes.

(8) Welders are penalized in wind because of greater difficulty in positioning parts, higher reject rates, and difficulty in maintaining gas shields for MIG and TIG welding.

(9) Riggers and fitters are penalized in high wind reflecting difficulty in positioning structures, crane operations. Some operations must stop in winds in excess of 20 mph. Nearly all operations stop with winds in excess of 40 mph.

(10) Extra penalties for welders for precipitation are brought about by extra time for drying joints, interrupted work, or rework. Penalties for other crafts reflect more difficult working conditions.

(11) Fog directly affects only the crane operations and the riggers and fitters who work more closely with the crane operators.

(12) The absence of shade tends to increase the effective outside temperature about 10°F causing an additional 30% loss of productivity in the sun when the temperature is above 80°F. We will assume that outside workers are in the shade half of the time.

EXHIBIT C

ASSUMPTIONS OF PRODUCTIVITY FOR WORKERS PROTECTED BY THE SHIP'S STRUCTURE

Workers are generally protected from wind and rain. The effectIve temperature is the dry bulb temperature. These productivities assume no-additional heating, cooling, or dehumidifying, but assume minimum ventilation to remove fumes from painting and welding.

(1) At temperatures above 80°F, a 5% penalty is assessed for buildup of heat from men and equipment. Heat from welding is assumed to cause an additional 5% penalty.

(2) Heat provided by welding increases productivity to 100% in the temperature range of 30-39°F.

(3) Painters' 70% productivity in 30-39°F temperature range reflects loss of productivity below freezing point, time waiting for temperature to rise, drying surfaces, etc.

(4) Loss of productivity in high wind and rain is caused by increased difficulty and delays in supplying needed parts, tools, and materials; drafts, dust, leaks, and noise interfering with work and causing uncomfortable or more hazardous working conditions; hesitancy of workers to transfer between work stations involving exposure to the elements; extra work to secure parts and equipment; and general interdependency on some outside work.

(5) Without drying equipment, relative humidity within ship is assumed to be the same as outside. In many instances, it is worse, particularly below the water line during outfilling.

(6) Lack of shade is assumed to increase temperature within the ship, reducing productivity further

EXHIBIT D

ASSUMPTIONS TO BE USED IN THE CALCULATIONS

(1) The annual hourly occurrences of effective temperature and dry bulb temperature will be used for the Productivity measurements for each' shift.

(2) The percentage occurrence of wind will be averaged for each shift.

(3) The percentage occurrence of precipitation and >90% relative humidity will be averaged for each full shift.

(4) The annual % frequency of fog will be applled to each shift.

(5) The correction for lack of shade will De made to that portion of the shift affected. We will assume shade and cloud cover are beneficial from 9 a.m. through 6 p.m. when the dry bulb temperature exceeds 80°F.

APPENDIX B

WEATHER DATA FOR U. S. SHIPYARD LOCATIONS

A summary of annual weather observations near each shipbuilding location is presented in Exhibit A. These tables were taken from a "Summary of Hourly Observation" from the Decennial Census of United States Climate, 1951-1960, U. S. Department of Commerce. Exhibit A also contains precipitation data for Seattle and Mobile covering a five-year period and precipitation data for Newark, New Jersey, which was substituted for the missing precipitation data for New York Internatioal.

The tables in Exhibit A are reproduced from the best available copies. These data are not used directly in the computer model. For use in the computer model, these annual data were disaggregated into frequencies of occurrence for the three standard work shifts (Exhibit B). These data (Exhibit B) were input to our computer model and are the same data a shipyard would use.

APPENDIX B, EXHIBIT A

ANNUAL SUMMARIES OF HOURLY WEATHER OBSERVATIONS

A TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

WIND / REL. HUMID. / TEMP (F)	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
99/ 95		+						+						+											1
94/ 90		+	+				+	8	3					3	+										14
89/ 85	+	1	2				1	22	23	+			1	4	4	+			+		+				58
84/ 80		2	5	1	+		2	37	62	7	+		2	11	17	1	+		+	+	+	+			149
79/ 75	+	4	9	5	2	1	4	65	95	30	10	1	2	19	21	6	2	+		1	1	+			275
74/ 70	+	3	11	9	12	9	4	59	109	58	42	26	3	19	24	9	5	2	1	1	1	+			407
69/ 65	+	3	12	14	23	55	4	50	106	67	84	128	4	20	23	10	9	11	1	1	1	+	+	1	627
64/ 60	+	2	10	14	31	112	4	52	100	73	91	191	3	26	30	11	9	16	+	1	1	1	+	3	780
59/ 55	+	3	9	14	30	115	5	46	102	65	101	201	4	24	32	10	10	29	+	1	1	1	1	5	808
54/ 50	+	3	10	13	27	99	4	41	88	58	89	197	4	27	26	11	9	41	1	2	1	1	1	4	760
49/ 45	+	4	10	12	25	88	2	44	99	62	90	168	2	24	34	13	14	46		1	2	1	1	10	748
44/ 40	+	4	15	15	23	75	2	36	100	69	89	179	1	18	45	17	19	47	+	1	4	1	1	11	772
39/ 35	+	4	16	16	27	79	1	30	120	92	96	181	1	20	49	21	18	51	+	2	3	2	2	7	839
34/ 30		4	17	18	32	82	1	30	130	88	89	166	1	18	49	17	15	49	+	2	4	1	1	7	820
29/ 25		4	17	16	27	53	1	28	120	82	70	72	+	17	41	12	9	17	+	2	4	1	1	4	599
24/ 20		3	14	13	21	20	1	21	95	46	45	42	1	11	31	10	8	13	+	1	3	1	+	2	408
19/ 15	+	2	13	13	15	12	+	16	68	38	34	28	+	8	21	6	6	6		1	1	1	1	+	293
14/ 10		1	8	7	14	5	+	11	49	25	24	11	+	5	16	4	4	1		+	1	1	1	+	190
09/ 05		1	5	6	12	+	1	11	28	16	18			2	4	1	2			+	+		1		109
04/ 00	+	2	4	4	5		+	7	16	10	8		+	1	2	1	1								60
-01/-05		1	2	2	2		+	4	6	7	5		+	1	1	+									29
-05/-10		1	2	1	1		+	2	3	3	2				+										15
-11/-15			+	1				1	2	2															5
-16/-20			+	+				+	+	+															1
TOTAL	2	50	196	195	329	806	36	623	1522	900	987	1591	29	277	471	161	140	330	4	17	27	9	11	56	3767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole number, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY																								NO. OF DAYS WITH
	AM HOUR ENDING AT												PM HOUR ENDING AT												
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	31	26	27	25	31	34	34	33	33	35	33	31	32	33	36	37	37	34	33	35	34	34	30	31	50
.01 IN	10	12	14	14	11	10	10	10	9	8	8	7	7	7	8	8	9	12	10	9	10	11	11	10	11
.02 TO .09 IN	19	18	20	20	21	21	18	19	19	18	17	17	16	16	13	14	18	18	19	17	18	16	18	19	42
.10 TO .24 IN	4	4	4	6	5	6	5	5	5	4	4	4	5	5	5	4	3	3	3	4	4	4	3	4	26
.25 TO .49 IN	1	1	1		1	1	1	1	+	1	1	+	1	1	1	1	+	1	1	1	+	+	1	1	21
.50 TO .99 IN	+	+	+	+	+	+	+	+	+	+	+	+		+	+	1	+	+	+	+			+		22
1.00 TO 1.99 IN														+	+	+		+							8
2.00 IN AND OVER																									1
TOTAL	65	63	65	65	69	71	68	68	65	66	63	60	61	62	64	66	67	67	66	65	65	67	64	65	182

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET)									
	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OVER [illegible]	TOT.
0 TO 1/8	1.0	.3	+	+		+	+	+	.1	1.5
3/16 TO 3/8	.3	.5	.1	+	+		+	+	.1	1.0
1/2 TO 3/4	+	.9	.5	.2	+	+	+	+	.1	1.8
1 TO 2 1/2	+	.9	2.5	2.0	.6	.2	.2	.3	.6	7.4
3 TO 6		.1	.9	2.7	1.5	.7	.8	1.2	3.9	11.7
7 TO 15			.1	1.0	2.3	2.4	5.1	9.3	56.4	76.6
20 TO 30										
35 OR MORE										
TOTAL	1.3	2.6	4.0	5.8	4.5	3.3	6.2	10.6	51.5	100

A

	TOTAL OBS.
	1
	14
	58
	149
	275
	407
1	627
3	780
5	808
4	760
10	748
11	772
7	839
7	820
4	599
2	408
+	293
+	190
	109
	60
	29
	15
	5
	1
56	3767

).

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR) 0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 OVER	TOTAL	AV. SPEED
N	.4	2.5	3.3	2.1	.4	.1	+	+		8.9	10.5
NNE	.2	1.1	1.6	1.6	.4	.1	+	+		5.1	11.9
NE	.1	.8	1.0	.5	.2	.1	+			2.7	10.3
ENE	.1	.7	1.0	.7	.2	.1	+	+		2.8	11.6
E	.2	.9	1.5	1.0	.2	.1	+	+	+	3.9	11.1
ESE	.1	.7	1.0	.6	.1	+	+		+	2.6	10.1
SE	.1	.7	.6	.4	.1	+	+	+		2.0	9.5
SSE	.2	.8	1.5	1.1	.1	.1	+	+	+	3.9	11.2
S	.3	1.7	3.1	2.8	.5	.1	+	+		8.5	11.3
SSW	.3	2.2	2.7	1.4	.2	+				6.9	9.5
SW	.4	2.5	2.5	1.0	.1	+	+			6.6	8.7
WSW	.5	2.9	2.8	1.7	.4	.1	+			8.4	9.9
W	.7	3.6	2.7	1.5	.4	.1	+			9.1	9.2
WNW	.6	3.3	2.6	1.5	.3	.1	+			8.5	9.2
NW	.6	3.0	2.5	1.6	.3	.1	+	+		8.0	9.3
NNW	.3	2.2	2.4	1.8	.3	+	+			7.2	10.2
CALM	4.8									4.8	
TOTAL	10.1	29.8	32.9	21.5	4.3	1.2	.2	+	+	100	9.6

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10 0-3	4-7	8-10	WIND SPEED (M.P.H.) 0-3	4-12	13-24	25-& OVER	RELATIVE HUMIDITY (%) 0-29	20-49	50-69	70-79	80-89	90-100
00	42	10	47	15	70	14	1	+	2	15	14	22	47
01	42	10	48	16	69	15	1		1	15	14	20	50
02	42	10	48	16	69	14	1		1	13	14	21	52
03	40	11	49	15	70	14	1		1	12	13	21	53
04	37	12	50	15	69	15	1		1	11	13	20	54
05	36	13	52	16	68	15	1		1	11	13	21	53
06	36	12	53	15	68	16	1	+	1	14	16	23	46
07	35	12	53	12	67	19	1	+	3	20	18	21	37
08	34	12	53	10	63	26	1	+	8	32	18	16	26
09	35	12	53	7	60	31	2	+	16	37	14	12	20
10	34	13	53	5	57	36	2	1	23	38	12	10	17
11	31	16	52	4	53	41	2	2	27	37	10	9	15
12	30	17	52	3	50	44	3	2	29	36	10	9	14
13	30	17	52	2	46	47	3	3	31	35	10	8	13
14	31	18	51	2	48	48	2	3	29	35	11	9	13
15	31	18	51	2	51	45	2	3	26	36	12	10	14
16	33	16	51	4	57	38	2	2	20	37	13	11	16
17	35	14	51	5	64	30	1	1	14	35	17	14	18
18	35	14	51	8	67	23	1	1	10	31	19	18	22
19	37	12	50	10	68	20	1	+	[illegible]	27	19	20	27
20	40	11	49	12	68	18	1	+	4	24	17	21	34
21	41	11	48	14	68	17	1	+	3	21	16	21	38
22	42	11	47	15	68	16	1		3	19	16	21	41
23	43	10	47	16	68	15	1	+	2	17	16	22	44
AVG	36	13	51	10	63	26	1	1	11	25	14	17	32

PORTLAND, MAINE
Municipal Airport

A TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
RH GROUP / TEMP (F)	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	
104/100								+						+											+
99/ 95							1	4	+				1	4	+					+					10
94/ 90			+				2	12	3				1	15	4					1	+				39
89/ 85		1	1				3	38	24	+			3	32	21	+			1	2	1				127
84/ 80	+	1	2	+			5	56	70	12	1		6	39	40	5			+	3	2	+			245
79/ 75	+	2	4	4	2		5	68	122	58	31	5	8	44	50	16	6	2	2	4	1	1	1		433
74/ 70	+	2	9	9	9	6	9	66	153	96	94	50	10	45	50	26	22	6	2	3	2	1	1	1	676
69/ 65	+	2	8	11	14	25	8	52	176	101	129	111	8	44	55	21	23	14	2	5	3	2	2	2	819
64/ 60	+	2	9	10	14	21	8	52	139	100	121	121	13	45	64	23	22	22	2	5	3	2	3	4	804
59/ 55	+	2	6	8	13	23	10	55	121	79	97	127	12	49	60	28	29	34	2	6	4	1	6	8	781
54/ 50	+	2	12	6	10	15	6	52	121	72	82	109	9	55	67	32	37	46	2	7	5	4	6	10	766
49/ 45	+	2	8	7	7	12	5	55	130	73	81	90	8	53	78	30	36	44	2	10	8	2	3	14	757
44/ 40	+	3	10	9	8	11	3	49	137	87	75	81	5	57	104	43	39	52	2	11	13	6	4	20	828
39/ 35	+	3	11	7	11	12	4	45	141	77	81	79	5	63	115	37	41	61	1	13	13	3	6	21	848
34/ 30	+	4	9	6	7	10	3	55	138	49	38	52	5	70	94	24	21	38	2	14	13	2	3	19	674
29/ 25	1	4	7	3	2	2	4	43	86	23	19	11	5	64	77	12	11	8	2	19	12	3	4	8	429
24/ 20	+	3	3	1	2	+	4	32	48	9	10	2	4	47	56	5	7	2	2	10	7	2	2	+	256
19/ 15	+	1	2	1	+		2	22	20	4	4	+	4	37	29	5	4	+	+	10	3	2	1		151
14/ 10			+	+			+	11	9	1	2	+	2	20	15	4	1		1	5	3	+	1		74
09/ 05								4	4	+	1		1	10	10	1	1		2	1	1	+			35
04/ 00							+	1	+				+	1	1	+									4
-01/-05							+	2	+					2	3	+	+		+	1					9
-06/-10														+	+					+					1
-11/-15															+										+
TOTAL	3	34	100	80	100	137	81	774	1649	843	865	838	112	796	991	312	299	330	27	128	94	30	40	107	8767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY																								NO. OF DAYS WITH
	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	34	38	39	39	39	41	38	41	40	39	41	37	35	35	37	36	33	35	35	34	38	37	36	34	62
.01 IN	10	10	12	12	13	10	11	11	10	10	10	9	10	10	9	11	12	11	12	12	10	12	11	12	16
.02 TO .09 IN	17	15	16	17	15	17	20	16	16	17	15	16	16	16	14	16	17	18	17	18	15	15	16	17	38
.10 TO .24 IN	6	7	7	5	6	5	4	5	6	5	5	5	5	5	6	6	5	4	5	3	4	5	5	6	24
.25 TO .49 IN	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21
.50 TO .99 IN	+	+	+	1	+	+	+	+	+	+	+	+	+	+	1	+	+	+	+	+	+		+		21
1.00 TO 1.99 IN								+	+	+	+	+	+	+	+	+		+	+	+					11
2.00 IN AND OVER																									2
TOTAL	68	72	74	73	73	74	75	75	74	71	72	68	68	67	67	70	68	71	70	67	69	69	69	69	196

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET)									
	0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9900	OVER 9900	TOT.
0 TO 1/8	+	+	+	+	+		+		+	+
3/16 TO 3/8	+	+	+	+	+	+	+		+	1
1/2 TO 3/4	+	+	+	+	+	+	+	+	+	1
1 TO 2 1/2		+	1	2	1	+	+	+	1	5
3 TO 6		+	1	3	2	1	1	1	8	16
7 TO 15	+	+	+	2	3	3	5	8	56	76
20 TO 30									+	+
35 OR MORE									+	+
TOTAL	+	1	2	6	6	3	6	10	65	100

BOSTON, MASS.
Logan Int. Airport

URRENCES:

	25 MPH AND OVER						TOTAL OBS.
							+
		+					10
		1	+				39
	1	2	1				127
	+	3	2	+			245
2	2	4	1	1	1		433
6	2	3	2	1	1	1	676
4	2	5	3	2	2	2	819
2	2	5	3	2	3	4	804
4	2	6	4	1	6	8	781
6	2	7	5	4	6	10	766
4	2	10	8	2	3	14	757
2	2	11	13	6	4	20	828
1	1	13	13	3	6	21	848
8	2	14	13	2	3	19	674
8	2	19	12	3	4	8	429
2	2	10	7	2	2	+	256
+	+	10	3	2	1		151
	1	5	3	+	1		74
	2	1	1	+			35
							4
	+	1					9
		+					1
							+
0	27	128	94	30	40	107	6767

livided by 10).
sums exactly
).5.

... AT					NO OF DAYS WITH
8	9	10	11	MO	
34	38	37	36	34	62
12	10	12	11	12	16
18	15	15	16	17	38
3	4	5	5	6	24
1	1	1	1	1	21
+	+		+		21
+					11
					2
67	69	69	69	69	196

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED									
N	+	1	2	2	+	+	+	+		5	17.0
NNE	+	1	1	1	+	+	+	+	+	3	13.3
NE	+	1	1	1	1	+	+	+	+	4	14.2
ENE	+	1	1	1	1	+	+	+	+	4	14.1
E	+	1	2	2	+	+	+	+	+	5	12.9
ESE	+	1	2	2	+	+	+			5	12.0
SE	+	1	2	1	+	+	+		+	4	10.8
SSE	+	1	1	1	+	+	+	+	+	3	10.4
S	+	1	2	1	+	+	+	+	+	4	11.0
SSW	+	1	3	2	1	+	+	+	+	7	13.0
SW	+	1	4	5	1	+	+	+		12	13.3
WSW	+	1	3	3	1	+	+	+		7	13.0
W	+	1	2	3	1	+	+	+		8	14.2
WNW	+	1	3	4	2	1	+	+		11	14.6
NW	+	1	3	4	2	1	+	+	+	11	15.2
NNW	+	1	2	3	1	+	+	+		7	13.6
CALM	1									1	
TOTAL	3	12	33	35	12	4	1	+	+	100	13.3

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10			WIND SPEED (M.P.H.)				RELATIVE HUMIDITY (%)					
	0-3	4-7	8-10	0-3	4-12	13-24	25- & OVER	0-29	30-49	50-69	70-79	80-89	90-100
00	43	8	49	4	53	39	3	+	10	34	18	19	20
01	42	9	49	4	54	38	3	+	9	33	18	19	21
02	43	9	49	4	55	37	3	+	8	32	17	20	23
03	42	9	50	4	56	36	4	+	7	31	18	21	23
04	40	9	51	5	55	37	3	+	7	29	19	21	24
05	38	9	52	5	56	36	3	+	6	29	20	21	24
06	37	10	53	4	54	39	3	+	7	32	20	20	22
07	36	10	54	4	50	42	4	+	10	36	18	18	19
08	36	11	53	4	46	45	5	+	16	38	16	14	15
09	36	11	53	3	43	48	6	1	24	38	12	12	13
10	34	12	53	3	40	51	7	3	30	34	11	10	12
11	32	15	53	2	38	54	7	4	34	32	10	9	11
12	31	17	52	2	35	55	8	6	36	30	10	9	10.
13	30	17	53	1	32	59	6	8	36	29	10	9	9
14	31	17	52	1	31	60	8	8	36	28	9	9	9
15	31	17	52	1	32	61	6	8	34	28	10	9	9
16	33	14	53	1	35	58	7	7	32	29	11	10	10.
17	35	13	51	2	39	54	5	5	29	30	12	12	11
18	37	12	51	2	44	50	4	4	25	32	14	12	14
19	38	12	50	3	47	46	4	2	21	33	15	15	15
20	40	11	49	3	48	45	4	1	17	35	15	16	16.
21	40	11	49	4	49	43	4	1	15	35	15	17	17
22	41	10	49	4	50	43	4	+	13	35	16	18	18
23	42	9	49	4	52	41	4	+	11	35	16	19	19
AVG	37	12	51	3	46	46	5	3	20	32	15	15	16.

BOSTON, MASS.
Logan Int. Airport

6

A TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

WIND / REL HUMID / TEMP (°F)	0-4 MPH						5-14 MPH						15-24 MPH						25 MPH AND OVER						TOTAL OBS
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
04/100													+						+						+
99/95							1	2	+					1	+										5
94/90			+				+	13	4				1	8	2					+					28
89/85		1	1				2	28	34	1			2	14	14	1				+	1				96
84/80		3	7	3	1		3	47	84	28	6	+	4	27	34	12	2		1	1	2	1	+		263
79/75	+	7	12	12	12	6	5	76	122	88	74	28	6	40	45	32	21	8	1	1	1	3	2	+	604
74/70	1	6	16	15	34	43	7	72	148	105	141	133	7	32	54	32	38	30	1	2	2	2	3	3	926
69/65	+	6	20	22	31	40	8	61	152	105	129	130	7	37	48	20	28	23	1	2	3	1	2	6	877
64/60	1	5	15	16	24	30	9	56	125	89	101	102	8	39	46	22	25	28	1	3	3	1	2	4	754
59/55	+	5	16	16	21	28	6	62	114	79	84	105	6	43	57	24	29	30	1	3	3	2	5	8	745
54/50	+	5	17	14	18	23	4	55	126	77	76	97	3	38	59	23	26	41	+	3	5	2	3	11	722
49/45	+	4	18	16	19	22	4	54	128	78	77	104	3	47	80	28	30	50	1	6	7	4	4	14	796
44/40	+	5	16	14	17	17	2	46	155	91	82	102	2	50	98	32	28	47	1	9	9	3	4	9	838
39/35	+	5	23	15	16	16	1	44	185	85	78	89	1	44	108	30	27	49	+	9	17	2	4	10	858
34/30	+	6	19	10	6	8	2	38	149	49	39	44	2	43	99	19	12	27	+	9	15	1	1	6	603
29/25	+	2	8	4	2	1	1	28	87	19	9	11	3	40	79	5	5	5	1	7	11	1	1	2	330
24/20	+	3	4	2	1	+	+	27	48	6	3	1	2	27	40	3	7	3	+	2	7	+	1	2	188
19/15							+	+	1					1	+	+							+		2
14/10			+					4	6	1	+	+	+	7	5	1	+			2	1				26
09/05								2	2	+				1	4	+				+	+				10
04/00								+	+					+	1										1
TOTAL	3	62	196	158	201	234	54	727	1691	904	900	945	56	560	888	284	278	341	10	65	86	24	30	72	8767

In Table A , occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

DATA NOT AVAILABLE

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET)									
	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOT
0 TO 1/8	+	+	+	+			+	+	+	1
3/16 TO 3/8	+	+	+	+	+	+	+	+	+	1
1/2 TO 3/4	+	+	+	+	+	+	+	+	+	1
1 TO 2 1/2		+	1	1	1	+	+	+	3	6
3 TO 6	+	+	1	3	2	1	1	2	12	21
7 TO 15	+	+	+	1	3	2	5	7	52	70
20 TO 30										
35 OR MORE										
TOTAL	+	1	2	9	5	3	7	9	67	100

A

[illegible]		TOTAL OBS
		+
		5
		28
		96
+		243
2	+	604
3	3	926
2	4	877
2	4	754
5	8	745
3	11	722
4	14	796
4	9	838
4	10	858
1	6	603
1	2	330
1	2	188
+		2
		26
		10
		1
30	72	3767

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

HOURLY OBSERVATIONS OF WIND SPEED

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N	+	1	3	2	1	+	+			7	11.5
NNE	+	1	2	2	1	+	+	+		6	11.6
NE	+	1	2	1	+	+	+	+	+	5	11.3
ENE	+	1	1	1	+	+	+	+		4	10.4
E	+	1	1	1	+	+	+	+	+	3	10.7
ESE	+	1	1	1	+	+	+			3	10.5
SE	+	1	1	1	+	+	+			3	11.2
SSE	+	1	2	2	1	+	+			6	12.5
S	+	2	4	3	1	+	+	+		10	12.2
SSW	+	2	4	3	1	+	+			9	11.4
SW	+	2	3	2	+	+	+			8	10.6
WSW	+	1	3	2	1	+	+	+		8	12.4
W	+	1	2	2	1	+	+		+	6	14.0
WNW	+	1	2	3	1	+	+	+		8	14.5
NW	+	1	2	3	1	+	+	+		8	14.1
NNW	+	1	2	2	1	+	+	+		7	12.7
CALM	2									2	
TOTAL	6	17	35	28	10	3	+	+	+	100	12.0

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10			WIND SPEED (M.P.H.)				RELATIVE HUMIDITY (%)					
	0-3	4-7	8-10	0-3	4-12	13-24	25- & OVER	0-29	30-49	50-69	70-79	80-89	90-100
00	46	11	42	9	61	28	2	+	8	30	17	21	24
01	46	10	44	9	62	27	2	+	7	29	17	21	25
02	45	11	44	10	61	27	2	+	6	29	17	22	27
03	46	10	44	11	61	27	2	+	5	28	17	21	28
04	44	11	45	11	61	26	2	+	5	27	17	22	30
05	40	12	48	11	62	25	2		4	27	18	21	30
06	37	13	50	10	60	27	2		4	29	18	20	28
07	35	14	51	9	56	32	2	+	6	34	18	20	22
08	35	13	52	7	52	38	3	+	11	39	16	17	17
09	35	14	51	6	50	40	4	1	18	40	15	13	14
10	35	16	50	4	48	44	4	1	25	38	14	11	12
11	33	16	50	3	45	48	4	2	30	36	12	9	11
12	32	18	50	2	43	50	5	3	33	34	11	9	10
13	32	18	50	2	40	53	5	4	34	33	11	9	9
14	31	19	50	2	37	56	5	5	32	34	11	9	9
15	32	18	50	2	38	55	6	5	30	35	11	10	9
16	32	18	51	2	40	54	4	4	26	35	13	11	10
17	33	17	49	2	45	49	4	3	22	35	15	13	11
18	35	16	48	3	49	45	4	2	19	34	17	15	14
19	38	15	47	5	53	39	4	1	15	33	18	17	16
20	41	14	45	6	54	37	3	1	13	31	18	19	18
21	44	13	43	7	57	34	2	1	12	30	19	19	20
22	45	13	42	7	59	32	2	+	11	30	19	20	20
23	45	12	43	8	60	30	2	+	9	30	17	21	22
AVG	38	14	47	6	52	38	3	1	16	33	16	16	18

B

NEW YORK, NEW YORK
Int. Airport (Idlewil

TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

WIND SPEED / REL. HUMID. / TEMP (°F)	0-4 MPH						5-14 MPH						15-24 MPH						25 MPH AND OVER						TOTAL OBS
	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	
/100							+	+					+	+											1
/ 95	1	1	+				1	10	1				1	2	1										17
/ 90	+	6	2				2	37	16				+	7	4					+					74
/ 85	1	10	11	1			7	69	83	4			1	19	19	+			+	+	+				225
/ 80	2	15	25	9	2		8	102	138	45	11	+	4	23	28	7	1			+	+	+			420
/ 75	2	16	28	25	26	16	11	105	146	86	84	37	5	24	22	11	7	3		+	+	+	+	+	655
/ 70	2	15	31	26	45	60	14	94	148	96	121	120	7	23	25	13	11	10	+	1	1	1	1	2	864
/ 65	2	12	29	29	46	67	11	80	128	93	104	118	6	24	23	9	13	12	1	1	+	+	+	1	808
/ 60	1	10	22	30	43	46	11	74	118	82	84	99	5	34	27	10	15	17	1	1	1	1	2	1	735
/ 55	1	9	23	27	36	41	8	77	113	70	78	97	5	36	34	13	15	19	1	2	1	1	1	2	710
/ 50	+	10	24	20	32	34	5	70	126	61	67	87	4	35	29	14	15	23	1	2	2	1	1	1	663
/ 45	1	11	27	24	29	34	3	71	140	71	64	77	4	46	43	9	15	23	1	4	3	1	1	1	701
/ 40	1	9	29	25	32	35	3	67	159	73	60	81	3	47	60	12	17	33	1	4	2	1	2	3	758
/ 35	+	10	32	30	39	34	1	61	192	88	74	75	2	48	58	15	16	31	1	5	4	1	1	2	818
/ 30		8	35	27	33	29	2	70	164	63	45	49	2	42	50	6	6	15		4	3	+		3	654
/ 25		4	18	12	15	6	2	52	100	26	16	6	2	29	32	2	4	4		3	2	+	1	1	335
/ 20		4	9	3	4	4	1	31	64	10	6	1	2	18	20	4	3	2		1	2	+	1	+	189
/ 15		1	7	2	2	1	1	17	30	7	3	+	1	13	12	1	2			1	2		+		100
/ 10		1	2	2	1	+	+	6	10	1	1	1		4	4	+					+	+			32
/ 05			1	+	1	+		1	2	+	+			+	3	+									9
TOTAL	14	152	351	292	384	408	91	1092	1875	875	815	849	53	474	493	126	140	191	5	31	23	7	10	17	8767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY — AM HOUR ENDING AT												PM HOUR ENDING AT												NO. OF DAYS WITH
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	24	25	26	27	26	27	30	30	33	32	31	26	29	29	28	28	27	25	26	27	27	25	26	25	59
.01 IN	8	7	7	7	8	7	8	8	6	7	6	8	7	5	6	6	6	7	8	7	9	7	8	7	10
.02 TO .09 IN	13	16	15	14	13	16	14	14	13	13	13	13	12	13	13	14	14	13	13	13	12	14	15	14	32
.10 TO .24 IN	5	5	5	5	6	5	5	3	3	2	3	3	3	3	3	4	3	3	4	4	3	4	4	4	25
.25 TO .49 IN	1	1	1	1	2	2	1	2	1	1	+	+	1	+	1	1	1	1	1	2	1	1	1	1	19
.50 TO .99 IN	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	1	1	+	+	+	+	20
1.00 TO 1.99 IN			+									+			+	+		+	+	+					8
2.00 IN AND OVER																								+	1
TOTAL	51	53	54	54	54	56	58	57	57	55	54	50	52	52	51	53	51	50	52	53	52	51	54	52	175

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET) 0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9500	OVER 9500	TOT
0 TO 1/8	+	+	+	+	+		+	+	+	1
3/16 TO 3/8	+	+	+	+	+	+	+	+	+	+
1/2 TO 3/4	+	+	+	+	+	+	+	+	+	1
1 TO 2 1/2		+	1	2	1	+	+	+	3	8
3 TO 6		+	+	3	3	1	2	3	16	28
7 TO 15			+	1	2	2	5	7	46	62
20 TO 30						+	+	+	+	+
35 OR MORE										
TOTAL	+	1	2	6	6	3	7	10	66	100

PHILADELPHIA, PENNA.
Int. Airport

CURRENCES:

	25 MPH AND OVER						TOTAL OBS
							1
							17
		+					74
	+	+	+				225
		+	+	+			420
3		+	+	+	+	+	655
10	+	1	1	1	1	2	864
12	1	1	+	+	+	1	808
17	1	1	1	1	2	1	735
19	1	2	1	1	1	2	710
23	1	2	2	1	1	1	663
23	1	4	3	1	1	1	701
33	1	4	2	1	2	3	758
31	1	5	4	1	1	2	818
15		4	3	+		3	654
4		3	2	+	1	1	335
2		1	2	+	1	+	189
		1	2		+		100
			+	+			32
							9
191	5	31	23	7	10	17	8767

1 divided by 10).
ir sums exactly
n 0.5.

ING AT 8	9	10	11	MID	NO. OF DAYS WITH
27	27	25	26	25	59
7	9	7	8	7	10
13	12	14	15	14	32
4	3	4	4	4	25
2	1	1	1	1	19
1	+	+	+	+	20
+					8
				+	1
53	52	51	54	52	175

1
+
1
8
8
2
+

Q

B

PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 & OVER	TOTAL	AV. SPEED
N	+	2	3	2	+	+	+			8	9.9
NNE	+	1	2	1	+	+	+			6	10.4
NE	+	1	1	1	+	+	+			3	11.3
ENE	+	1	2	2	+	+	+			6	12.0
E	+	1	2	1	+	+	+			4	10.3
ESE	+	1	1	+	+	+	+			3	8.4
SE	+	1	1	+	+	+	+	+	+	3	8.0
SSE	+	1	1	+	+	+	+			3	7.9
S	+	2	1	1	+	+	+		+	4	8.8
SSW	+	2	2	1	+	+	+	+		6	10.0
SW	+	2	4	2	+	+	+			8	9.7
WSW	+	3	5	2	+	+	+			11	9.7
W	+	2	2	1	+	+	+			6	9.6
WNW	+	2	3	2	1	+	+	+		8	11.6
NW	+	2	2	2	1	+	+	+		7	11.7
NNW	+	2	2	2	1	+	+	+		7	11.6
CALM	7									7	
TOTAL	11	27	35	21	5	1	+	+	+	100	9.6

E

PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10: 0-3	4-7	8-10	WIND SPEED (M P H): 0-3	4-12	13-24	25-& OVER	RELATIVE HUMIDITY (%): 0-29	30-49	50-69	70-79	80-89	90-100
00	46	9	45	15	67	18	1	+	6	27	20	24	22
01	44	10	45	16	67	17	+		6	26	19	25	25
02	44	11	45	18	65	17	+		5	25	18	24	28
03	43	10	46	19	64	16	1		4	23	18	24	31
04	41	11	48	18	65	17	+	+	4	23	18	23	33
05	37	13	50	19	63	18	+	+	3	22	18	23	34
06	34	14	52	19	62	19	1	+	4	23	19	23	31
07	33	14	53	15	63	21	1	+	5	29	19	22	25
08	33	14	53	12	60	27	1	+	10	36	18	19	17
09	33	16	51	11	57	31	1	+	19	39	15	14	13
10	32	17	51	8	57	33	2	1	28	38	12	10	10
11	30	20	50	7	54	37	2	3	35	36	10	8	8
12	29	20	51	5	54	38	2	4	42	32	9	6	7
13	27	20	53	5	52	41	2	6	45	29	7	6	7
14	27	23	51	5	52	41	2	7	46	28	7	6	6
15	27	22	51	5	51	41	2	7	47	27	6	6	7
16	29	20	50	5	55	39	2	6	44	30	7	7	7
17	33	19	48	5	61	32	1	4	36	36	8	7	8
18	36	16	48	6	66	27	1	2	28	41	11	9	9
19	38	15	47	6	70	23	1	1	20	42	15	11	10
20	42	13	45	9	70	20	1	1	13	41	19	14	12
21	44	12	44	10	70	19	1	+	10	36	22	17	14
22	45	12	43	12	68	19	+	+	9	33	22	20	17
23	46	10	44	14	67	19	1	+	8	29	22	23	19
AVG	36	15	49	11	62	26	1	2	20	31	15	15	17

PHILADELPHIA, PENNA.
Int. Airport

B

A TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
REL. HUMID. / TEMP. (F)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
14/100							1	4						+											2
19/ 95	1	2	+				3	12	1				1	5	+										23
14/ 90	+	4	3				2	49	27				2	15	7				+	+					109
19/ 85	1	9	10	1			5	71	101	7			2	23	30	2			+	1	1				263
14/ 80	1	11	17	9	2		8	91	149	61	13	1	3	27	32	10	1	+		1	1	1			438
19/ 75	1	12	16	13	15	9	8	96	140	99	99	47	7	29	29	14	12	6	+	2	2	1	1	1	655
14/ 70	1	7	16	13	24	49	11	70	145	98	139	194	10	26	31	11	11	14	+	2	2	1	+	3	883
59/ 65	1	8	12	14	22	51	10	60	124	98	123	153	9	32	30	12	15	12	2	2	1	1	1	1	794
54/ 60	1	9	12	14	24	34	8	62	109	83	109	120	8	38	32	17	17	21	1	3	4	1	1	2	729
59/ 55	1	8	10	10	21	33	11	66	95	71	97	119	7	44	36	15	17	24	1	4	3	1	1	1	696
54/ 50	1	9	11	9	19	29	7	68	112	61	90	109	7	47	39	10	15	22	+	7	1	1	+	2	683
49/ 45	1	9	16	10	17	30	3	74	125	64	77	87	4	50	50	12	12	20	+	8	4	1	1	1	673
44/ 40	+	6	20	15	19	36	5	65	154	76	68	100	5	55	66	14	15	28	1	10	7	1	1	4	770
39/ 35	+	7	22	18	21	38	2	49	175	86	75	88	2	43	67	15	10	23	1	9	4	1	1	2	755
34/ 30	+	9	22	19	28	33	1	45	159	71	64	71	1	38	44	7	6	14	+	8	5	1	1	1	642
29/ 25		3	12	11	13	2	+	23	98	44	29	11	1	19	34	4	5	4	+	3	3	+	+	1	328
24/ 20		2	6	8	6	2	+	11	56	23	19	4	1	11	23	3	4	1	+	1	3	+	1	+	184
19/ 15			3	3	4	1		5	29	18	8	1		3	10	1				3	2				89
14/ 10			3	1	2	+		2	12	8	6			2	6	1	+			1	2				43
9/ 05			+	1	+			+	2	1	1			+	1						1				7
4/ 00									1	+	+										+				2
TOTAL	9	107	213	170	234	354	87	919	1813	967	1016	1109	67	507	565	154	136	190	8	65	50	8	9	19	9767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY																								NO. OF DAYS WITH
	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	24	24	24	24	23	27	29	30	29	20	24	24	25	26	24	24	23	22	23	23	25	26	25	25	52
.01 IN	6	6	6	6	7	6	7	7	8	7	8	8	6	7	6	8	7	8	8	7	6	8	6	8	11
.02 TO .09 IN	13	14	15	14	15	14	14	13	13	13	13	12	12	12	14	13	14	14	13	13	13	14	14	13	33
.10 TO .24 IN	4	3	4	5	3	4	4	3	3	4	4	4	3	4	3	4	6	4	4	6	6	4	4	4	22
.25 TO .49 IN	1	1	1	1	1	1	+	1	1	1	+	+	+	1	1	1	1	1	1	1	2	1	1	1	22
.50 TO .99 IN	+	+	+	+		+	+	+	+	+	+		+	+	+	1	+	+	+	+	1	+	1	+	16
1.00 TO 1.99 IN				+	+		+					+		+	+	+	+	+		+	+	+		+	8
2.00 IN AND OVER																							+		3
TOTAL	50	48	49	49	45	53	55	52	54	52	49	49	47	49	49	51	50	50	50	49	51	91	51	51	167

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET)									
	0	100-200	250-450	500-950	1000-1900	2000-2900	3000-4900	5000-9500	OVER 9500	TOT
0 TO 1/8	+	+	+	+	+		+	+	+	1
3/16 TO 3/8	+	+	+	+	+		+	+	+	1
1/2 TO 3/4	+	+	+	+	+	+	+	+	+	1
1 TO 2 1/2	+	+	1	2	1	+	+	+	1	5
3 TO 6		+	+	2	2	1	1	2	9	18
7 TO 15		+	+	+	2	1	4	6	44	57
20 TO 30				+	+	+	1	1	15	17
35 OR MORE									+	+
TOTAL	+	1	2	4	4	3	6	10	69	100

A

	TOTAL OBS.
	2
	23
	109
	263
	438
	655
	683
	794
	729
	696
	683
	673
	770
	755
	642
	328
	184
	89
	43
	7
	2
	198767

B

PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR)										AV SPEED
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 OVER	TOTAL	
N	+	1	2	1	+	+				5	9.9
NNE	+	1	1	1	+	+	+			3	10.1
NE	+	1	2	1	+	+	+	+		5	10.5
ENE	+	1	2	1	+	+	+	+	+	5	10.9
E	+	1	2	1	+	+	+			5	9.3
ESE	+	1	1	+	+	+	+	+		3	8.8
SE	+	1	2	1	+	+	+	+	+	4	9.5
SSE	+	1	2	1	+	+	+	+	+	4	10.8
S	+	2	3	1	+	+	+	+		7	9.8
SSW	+	1	2	1	+	+	+	+		6	10.6
SW	+	2	3	1	+	+	+	+		8	9.9
WSW	+	2	3	1	+	+	+			6	9.9
W	+	2	4	2	1	+	+	+	+	9	11.2
WNW	+	2	3	3	2	1	+			11	13.3
NW	+	2	4	3	1	+	+	+		10	12.2
NNW	+	1	2	1	+	+	+			5	11.3
CALM	3									3	
TOTAL	7	24	39	22	6	2	+	+	+	100	10.4

E

PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10			WIND SPEED (M.P.H)				RELATIVE HUMIDITY (%)					
	0-3	4-7	8-10	0-3	4-12	13-24	25-& OVER	0-29	30-49	50-69	70-79	80-89	90-100
00	49	11	40	8	72	19	1	+	5	25	18	25	26
01	49	11	40	9	72	19	1	+	4	24	18	25	28
02	48	11	41	9	71	19	1	+	4	22	18	24	32
03	49	9	42	9	72	18	1		3	21	18	24	33
04	46	11	43	9	71	19	1		3	20	18	25	35
05	43	13	44	10	71	18	1		2	20	17	25	36
06	39	14	47	10	71	18	1		2	21	18	25	34
07	37	14	49	9	69	21	1		3	25	19	24	29
08	37	14	49	10	63	26	1	+	7	34	20	19	20
09	38	15	47	9	57	32	2	1	16	40	16	13	15
10	37	17	46	7	55	36	3	2	27	39	12	9	12
11	33	20	47	6	51	40	3	2	35	36	10	7	10
12	31	22	46	5	51	41	3	4	40	33	8	6	8
13	31	22	47	5	49	42	4	6	43	31	7	6	7
14	31	23	47	4	48	44	4	7	43	30	7	5	7
15	33	22	45	4	48	44	4	8	42	30	7	5	8
16	36	18	46	4	52	41	3	7	40	31	8	7	8
17	39	16	45	4	59	35	2	5	33	36	9	7	9
18	41	15	44	5	65	28	1	3	26	40	13	9	11
19	42	14	43	6	68	25	1	1	20	41	15	12	12
20	45	13	41	7	68	24	1	+	14	37	19	16	14
21	48	13	40	7	69	22	1	+	9	34	20	19	17
22	48	11	40	7	71	20	1	+	8	30	20	22	20
23	49	11	40	8	71	20	1	+	6	28	19	24	23
AVG	41	15	44	7	63	28	2	2	18	30	15	16	19

BALTIMORE, MARYLAND
Friendship Int. Airpor

A TEMPERATURE AND WIND SPEED—RELATIVE HUMIDITY OCCURRENCES:

WIND (M.P.H.) / REL. HUMID. / TEMP. (°F)	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OCC.
	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	
104/100								1																	1
99/ 95	+	2	+				1	12	1				+	3											19
94/ 90	+	9	8	+			1	40	52	+			+	10	15						+				126
89/ 85	+	10	31	4	+		1	47	136	17	2		1	15	32	2				+	1				297
84/ 80	+	10	34	27	11	2	3	54	161	104	34	1	1	21	34	17	7		+	2	1	1			524
79/ 75	+	10	28	33	58	61	5	56	156	122	162	79	2	19	54	30	26	10	+	1	2	1	1	4	916
74/ 70	1	7	26	32	73	149	5	47	137	108	157	138	3	19	65	44	35	18	+	1	4	2	2	9	1079
69/ 65	1	7	20	29	62	96	4	49	123	90	114	102	5	29	59	36	52	29	+	2	3	2	3	5	920
64/ 60	1	6	15	22	51	67	5	54	105	77	99	103	3	28	51	36	28	61	+	+	2	3	5	6	820
59/ 55	+	7	14	20	35	60	5	59	103	74	86	97	5	33	56	29	33	30	1	2	2	1	2	3	757
54/ 50	1	7	19	16	36	41	4	64	115	60	71	77	3	36	46	19	26	21	+	3	2	1	1	1	668
49/ 45	+	7	25	23	32	48	2	59	134	66	70	75	3	44	54	19	23	20	+	2	3	2	1	3	724
44/ 40	1	9	27	29	30	40	3	44	139	70	72	69	2	42	61	21	24	35	+	2	2	1	3	5	727
39/ 35	+	6	23	29	27	34	+	33	114	58	48	39	+	33	56	13	15	20		2	3	1	1	3	558
34/ 30	+	3	17	17	21	19	+	27	78	32	25	17	+	26	50	9	8	13		2	4	1	+	2	371
29/ 25		1	12	10	12	6		17	33	10	5	1	1	22	26	6	3	2	+	1	3	1	+	+	175
24/ 20			4	4	5	1		4	13	5	2	+	+	11	8	1	+		+	1	+		+		61
19/ 15			1	2	1			1	1	1	1			3	2				+	1	+				14
14/ 10														1						1					1
TOTAL	6	97	305	298	454	623	39	662	1598	894	946	803	29	394	669	283	290	245	3	24	31	16	19	66	3767

In Table A occurrences are for the average year (10-year total divided by 10).
In Table C occurrences are for the average year (5-year total divided by 5).
Values are rounded to the nearest whole number, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C 1/56 - 12/60 OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY																								NO. OF DAYS (OTHER)
	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	26	36	26	22	22	29	25	26	27	24	24	27	25	28	22	24	25	24	26	26	26	26	26	27	47
.01 IN	9	6	6	8	5	8	5	6	6	6	5	7	7	7	7	7	7	6	6	9	6	6	7	7	11
.02 TO .09 IN	11	11	12	13	17	24	16	12	12	11	12	12	13	11	14	16	15	13	12	12	11	12	13	15	33
.10 TO .24 IN	2	2	4	5	3	3	5	4	3	4	5	3	3	4	3	5	5	9	4	4	4	9	3	3	23
.25 TO .49 IN	1	1	2	1	2	+	1	1	2	1	1	1	1	1	2	2	5	1	2	1	2	1	1	+	20
.50 TO .99 IN		1	+	+		1	+		1			2	+	1	+	1	+	1	1	+		+	+		17
1.00 TO 1.99 IN	+	+	1											+	1	+	+	+		1	+				11
2.00 IN AND OVER													+												3
TOTAL	52	51	52	50	49	49	49	49	49	47	48	50	49	48	50	53	55	53	52	52	52	52	51	52	166

D PERCENTAGE FREQUENCIES OF CEILING-VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET)									
	0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9900	OVER 9900	TOT.
0 TO 1/8	.2	.2	+	+	+	+		+	.1	.6
3/16 TO 3/8	+	.3	+	+			+	+	.1	.4
1/2 TO 3/4	+	.3	.2	.1	+	+	+	+	.1	.8
1 TO 2 1/2		.3	.9	1.0	.3	.1	.2	.2	1.2	4.2
3 TO 6		.1	.7	3.0	2.1	1.0	1.9	2.4	38.1	38.8
7 TO 15		+	+	.9	2.3	1.9	3.7	5.5	31.0	55.3
20 TO 30										
35 OR MORE										
TOTAL	.2	1.1	1.9	4.9	4.7	3.1	5.4	8.0	70.6	100

NORFOLK, VIRGINIA
Municipal Airport

DITY OCCURRENCES:

	... M.P.H.			25 M.P.H. AND OVER						TOTAL OBS.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
										1
										19
						+				136
	2				+	1				297
	17	7		+	2	1	1			524
	30	26	10	+	1	2	1	1	6	916
	44	35	18	+	1	4	2	2	9	1079
	38	52	29	+	2	3	2	3	5	920
	36	33	41	+	+	2	3	5	6	820
	29	39	30	1	2	2	1	2	3	757
	19	24	21	+	3	2	1	1	1	668
	19	23	28	+	2	3	2	1	3	724
	21	24	35	+	2	2	1	3	5	727
	13	15	20		2	3	1	1	3	558
	9	8	13		2	4	1	+	2	371
	6	3	2	+	1	3	1	+	+	175
	1	+		+	1	+		+		61
				+	1	+				14
					1					1
	283	290	245	3	24	31	16	19	40	8767

total divided by 10).
otal divided by 5).
djusted to make their
s more than 0 but

MOUNTS:

R OF THE DAY									NO. OF DAYS WITH
P.M. HOUR ENDING AT									
	5	6	7	8	9	10	11	MID	
4	25	24	26	26	26	26	26	27	47
7	7	8	6	9	6	6	7	7	11
4	15	13	12	12	11	12	13	15	53
5	5	5	4	4	4	5	3	3	23
2	3	1	2	1	2	1	1	+	20
1	+	1	1	+		+	+		17
+	+	+		1	+				11
									3
3	55	53	52	52	57	58	51	52	166

)F

...	OVER ...	TOT.
+	.1	.6
+	.1	.4
+	.1	.8
.2	1.2	4.2
.4	10.1	78.8
.5	[illegible]	[illegible]
.0	70.6	100

NORFOLK, VIRGINIA
Municipal Airport

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR)										AV. SPE...
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 & OVER	TOTAL	
N	.5	1.1	1.7	2.1	.7	.1	+			6.5	11.
NNE	.4	1.4	2.5	2.7	.7	.1	+	+		7.0	12.
NE	.7	1.8	3.2	2.9	.7	.1	+	+		9.4	11.
ENE	.6	1.2	2.0	1.9	.5	.1	+	+	+	6.2	11.
E	.9	1.3	1.2	.5	.1	+	+			4.1	7.
ESE	.7	1.1	1.0	.4	+	+	+			3.3	7.
SE	1.0	1.5	1.2	.5	.1	+	+		+	4.2	7.
SSE	.8	1.5	1.4	.7	.1	+	+	+	+	4.4	8.
S	1.3	2.5	2.4	1.1	.2	+	+		+	7.5	8.
SSW	.9	2.4	3.4	2.5	.4	.1	+	+		9.7	10.
SW	1.2	2.6	3.9	3.3	.5	.1	+	+		11.6	10.
WSW	.7	1.3	1.6	1.7	.4	.1	+	+		6.0	10.
W	.7	1.1	1.3	1.1	.4	.1	+	+		4.7	10.
WNW	.4	.8	1.1	1.4	.5	.1	+		+	4.2	12.
NW	.6	1.1	1.2	1.2	.5	.1	+	+		4.6	11.
NNW	.3	.7	1.0	1.4	.5	.1	+		+	4.0	12.
CALM	1.9									1.9	
TOTAL	13.6	23.3	30.2	25.2	6.2	1.3	.2	+	+	100	10.

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10			WIND SPEED (M.P.H.)				RELATIVE HUMIDITY (%)					
	0-3	4-7	8-10	0-3	4-12	13-24	25 & OVER	0-29	30-49	50-69	70-79	80-89	90-100
00	49	12	39	20	55	24	1	+	4	20	18	28	29
01	49	13	38	19	56	24	1	+	4	19	17	27	32
02	49	12	40	20	54	25	1		3	18	17	27	35
03	48	12	40	21	53	25	1		3	18	15	27	37
04	46	13	41	20	53	26	1	+	3	17	15	27	38
05	43	14	43	21	53	25	1		2	17	15	26	39
06	39	14	47	19	53	27	1		2	17	17	28	35
07	38	14	49	14	54	31	1		3	21	21	29	26
08	37	15	48	11	52	36	1	+	6	31	25	22	16
09	38	15	47	8	50	40	1	+	12	41	22	15	10
10	39	14	47	7	49	42	2	+	19	46	16	11	8
11	37	16	47	6	48	44	2	1	26	45	13	8	7
12	36	18	46	5	48	45	2	2	31	42	12	8	6
13	35	19	45	4	48	46	2	3	34	39	11	7	6
14	35	19	46	4	49	45	2	4	35	37	11	7	6
15	36	18	46	4	51	43	2	4	34	37	11	7	7
16	35	18	47	6	55	37	2	3	30	39	13	8	8
17	36	17	47	10	58	31	1	2	22	40	15	11	9
18	38	15	47	13	60	26	1	1	15	38	20	16	11
19	40	15	46	16	60	23	1	+	11	34	21	19	14
20	43	14	43	19	58	22	1	+	7	27	23	24	17
21	45	14	42	19	57	22	1	+	6	25	21	27	21
22	46	14	40	20	55	24	2	+	6	22	20	28	24
23	48	12	40	20	54	25	1	+	5	21	19	29	26
AVG	41	15	44	14	53	31	2	1	13	30	17	19	19

P1

B

TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

[illegible]	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
/100							1	1						+											2
/ 95	+	4	+				1	15	2				1	2	+										30
/ 90	+	13	14				4	71	80	+			1	11	14	+					+				208
/ 85	1	14	43	4			6	69	261	41	2		2	19	63	10	1		+	+	1	+			536
/ 80	1	9	20	30	25	3	6	65	170	179	109	8	3	20	58	33	7	+	+	+	1	1	1		750
/ 75	1	6	13	20	92	167	6	47	122	114	272	312	5	16	48	45	35	13		+	2	3	2	1	1341
/ 70	3	6	9	15	48	228	16	53	96	88	171	450	7	25	37	33	47	64	1	+	1	3	4	6	1411
/ 65	3	7	9	11	27	92	17	53	86	80	123	318	11	30	34	25	34	69	1	1	2	2	1	5	1038
/ 60	2	8	8	8	18	71	15	56	95	67	97	261	9	35	28	20	31	46	+	1	2	1	1	1	882
/ 55	2	7	11	10	18	44	11	57	96	65	85	152	11	29	28	18	21	28	+	1	1	1	1	1	698
/ 50	1	6	11	10	18	28	10	49	107	60	73	102	10	27	35	17	18	20	+	1	2	1	+	1	609
/ 45	1	4	11	14	18	17	5	39	93	64	66	56	5	22	31	17	17	18	1	3	2	2	1	1	506
/ 40	+	2	7	8	16	14	3	28	70	52	51	22	2	20	29	18	17	9	+	2	3	1	1	+	377
/ 35		2	4	7	10	8	1	15	46	32	27	10	1	9	15	10	7	7		1	2	1	1	+	214
/ 30			2	4	3	3	+	9	31	15	11	4	+	7	11	4	1	1		+	1	1	+	+	109
/ 25			2	3	2	+		3	16	7	3	+		2	7	2	1	+			+	+	+		49
/ 20			+		+			+	5	1	1			+	1	+	+					+			7
/ 15				+					+	1	+			+	1	+	+				+	+			3
TOTAL	16	87	165	147	297	675	102	633	1374	866	1090	1697	67	273	439	250	237	274	4	10	19	18	13	17	3767

In Table A , occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

DATA NOT AVAILABLE

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET)									
	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OVER [illegible]	TOT
0 TO 1/8	+	+	+	+	+	+	+	+	+	1
3/16 TO 3/8	+	+	+	+	+	+	+	+	+	1
1/2 TO 3/4	+	+	+	+	+	+	+	+	+	1
1 TO 2 1/2		+	+	+	+	+	+	+	1	2
3 TO 6		+	1	1	1	+	1	1	4	9
7 TO 15	+	+	+	3	4	4	5	4	66	87
20 TO 30										
35 OR MORE						+			+	+
TOTAL	+	2	2	5	5	5	6	5	71	100

17

JRRENCES:

25 M.P.H. AND OVER						TOTAL OBS.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
						2
						30
		+				208
+	+	1	+			536
+	+	1	1	1		750
	+	2	3	2	1	1341
1	+	1	3	4	6	1411
1	1	2	2	1	5	1038
+	1	2	1	1	1	882
+	1	1	1	1	1	698
+	1	2	1	+	1	609
1	3	2	2	1	1	506
+	2	3	1	1	+	377
	1	2	1	1	+	214
	+	1	1	+	+	109
		+	+	+		49
			+			7
		+	+			3
4	10	19	18	13	17	3767

ivided by 10).
sums exactly
.5.

B

PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR)										AV SPEED
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 OVER	TOTAL	
N	+	2	4	3	2	+	+	+		11	12.3
NNE	+	1	2	1	+	+	+	+		6	10.5
NE	+	3	4	1	+	+	+			8	9.3
ENE	+	1	2	1	+	+	+			4	9.6
E	+	2	3	1	+	+				6	9.7
ESE	+	1	1	1	+	+	+	+		3	10.6
SE	+	2	3	1	+	+	+			7	10.0
SSE	+	2	3	1	+	+				7	9.7
S	+	3	3	2	1	+	+	+	+	10	10.5
SSW	+	1	2	2	1	+	+			6	12.3
SW	+	2	2	1	+	+	+	+		6	10.1
WSW	+	1	1	+	+	+	+			3	9.5
W	+	2	2	1	+	+				5	8.9
WNW	+	1	1	1	+	+	+			3	10.2
NW	+	2	2	1	1	+	+	+		6	11.0
NNW	+	1	2	1	1	+	+			5	12.5
CALM	5									5	
TOTAL	7	28	38	20	6	1	+	+	+	100	10.0

E

PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10			WIND SPEED (M.P.H.)				RELATIVE HUMIDITY (%)					
	0-3	4-7	8-10	0-3	4-12	13-24	25-& OVER	0-29	30-49	50-69	70-79	80-89	90-100
00	54	12	34	11	73	15	+	+	3	12	11	22	52
01	53	13	35	11	73	15	1		2	11	11	20	55
02	51	13	36	12	72	15	+		2	10	11	19	57
03	49	14	37	11	73	15	1		1	10	11	19	59
04	49	13	38	11	72	17	+		1	10	11	19	59
05	44	16	40	11	73	15	1		1	9	11	19	60
06	40	17	43	8	75	16	1		1	10	12	23	53
07	39	17	44	5	71	23	+		2	15	18	31	33
08	37	19	44	4	63	32	1	+	7	25	26	22	19
09	36	20	44	4	58	37	1	1	15	37	23	14	12
10	34	23	43	4	56	39	2	2	21	42	16	10	8
11	31	25	44	4	55	40	2	4	26	42	13	8	7
12	29	26	45	3	53	42	2	7	29	39	11	8	6
13	28	27	45	3	50	45	2	8	31	36	11	8	6
14	29	26	45	3	50	45	2	9	30	34	11	8	7
15	31	24	45	2	49	47	2	9	28	33	12	9	8
16	34	22	44	2	53	43	1	7	25	33	15	12	8
17	36	19	45	3	65	32	1	2	18	33	18	16	12
18	38	18	44	4	75	20	+	1	11	28	22	22	16
19	42	17	41	7	77	16	+	+	6	20	21	28	25
20	45	17	38	9	75	15	1	+	5	16	16	30	33
21	48	16	36	10	74	16	+	+	4	14	14	29	39
22	51	15	34	12	73	15	+	+	3	13	13	27	44
23	53	14	34	12	71	16	+	+	3	13	12	25	48
AVG	41	18	41	7	66	26	1	2	11	23	15	19	30

MOBILE
Bates

TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

[illegible]	0-4 MPH						5-14 MPH						15-24 MPH						25 MPH AND OVER						TOTAL OBS
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
100								+																	+
95	+	1					+	7	3	+															12
90	+	6	11	+			1	57	138	1				3	13										229
85	+	5	31	11	1		1	60	341	86	4		+	9	63	7	+				1	+			620
80	+	4	21	51	70	8	2	43	206	237	180	17	1	13	71	40	11	+		+	2	2	+		979
75	+	3	17	33	180	300	4	43	146	134	305	302	2	15	69	46	40	18		+	3	5	4	1	1671
70	1	9	15	20	76	197	8	46	105	98	186	238	5	24	50	33	37	34	+	1	2	2	4	2	1189
65	1	7	12	18	55	129	7	58	91	75	131	252	4	29	39	17	25	32	+	1	2	1	1	2	987
60	1	6	16	15	50	100	6	57	98	70	117	185	3	29	36	15	17	22	1	2	3	1	1	1	850
55	1	7	17	21	43	66	4	45	94	64	82	109	3	33	41	15	17	22	+	3	3	1	1	1	692
50	+	5	19	20	45	46	2	39	87	61	68	78	2	27	45	19	19	21	+	2	4	1	2	1	621
45	1	4	12	19	40	32	1	29	61	45	48	31	1	25	48	18	14	11		2	5	2	1	1	449
40	+	3	7	13	31	20	+	15	40	25	27	12	1	13	30	15	11	7	+	2	5	2	1	+	282
35		1	6	8	12	12		7	23	13	7	3		5	18	5	4	2		1	3	1	1	+	128
30			2	3	8	6		2	7	4	2	1		2	7	1	2	1		+	1	+			47
25			+	1	1	2			1	1	+	+		+	+	1	1	+							9
20					+	+			+	+	+				1	+									2
15															+										+
TAL	5	58	186	232	613	917	36	507	1440	911	1157	1227	21	235	529	232	198	170	2	13	33	18	16	11	8767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY																								NO. OF DAYS WITH
	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	16	14	16	18	16	17	20	18	17	18	20	22	27	26	27	24	22	21	22	19	17	17	16	14	50
.01 IN	4	4	5	3	4	4	2	3	3	4	4	6	5	4	7	7	6	6	5	4	4	2	4	4	11
.02 TO .09 IN	6	5	6	6	6	6	6	7	8	9	10	11	12	12	13	13	11	10	9	9	8	7	7	8	28
.10 TO .24 IN	2	3	2	3	3	3	3	3	3	4	3	4	5	6	5	5	5	4	3	4	2	2	3	2	19
.25 TO .49 IN	1	1	2	1	2	1	1	2	2	2	2	3	2	2	3	2	1	2	2	1	1	1	+	1	18
.50 TO .99 IN	+	+	1	1	+	1	1	+	1	1	1	1	1	2	1	1	1	1	1	1	+	1	1	1	18
1.00 TO 1.99 IN		+	+	+	+	+	+			1	+	+	1	1	+	+	+	+		+	+	+	+	+	12
2.00 IN AND OVER			+					+	+						+	+	+		+						5
TOTAL	29	28	31	31	32	31	33	32	33	37	41	48	52	52	55	51	47	45	41	37	33	30	31	29	160

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET)									
	0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9900	OVER 9900	TOT
0 TO 1/8	+	+	+	+	+	+	+	+	+	1
3/16 TO 3/8	+	+	+	+	+	+	+	+	+	1
1/2 TO 3/4	+	+	+	+	+	+	+	+	+	1
1 TO 2 1/2	+	+	1	+	+	+	+	+	1	2
3 TO 6		+	+	1	1	+	+	1	4	8
7 TO 15		+	+	2	4	3	3	4	72	88
20 TO 30										
35 OR MORE										
TOTAL	+	1	1	3	5	3	4	5	77	100

NEW ORLEANS, LA.
Moisant Int. Airport

ƆITY OCCURRENCES:

MPH			25 MPH AND OVER						TOTAL OBS.
									+
									12
									229
7	+				1	+			620
40	11	+		+	2	2	+		979
46	40	18		+	3	5	4	1	1671
33	37	34	+	1	2	2	4	3	1189
17	25	32	+	1	2	1	1	2	987
15	17	22	1	2	3	1	1	1	850
15	17	22	+	3	3	1	1	1	692
19	19	21	+	2	4	1	2	1	621
18	14	11		2	5	2	1	1	449
15	11	7	+	2	5	2	1	+	282
5	4	2		1	3	1	1	+	128
1	2	1		+	1	+			47
1	1	+							9
+									2
									+
232	198	170	2	13	33	18	16	11	8767

ear total divided by 10).
make their sums exactly
less than 0.5.

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION										TOTAL
N	+	1	2	2	1	+	+	+		6
NNE	+	1	2	2	1	+	+			6
NE	+	2	3	2	+	+	+	+		8
ENE	+	2	3	2	+	+	+	+	+	8
E	+	2	2	1	+	+	+			6
ESE	+	2	1	1	+	+				4
SE	+	2	2	1	+	+				5
SSE	+	3	3	2	+	+	+	+		8
S	+	3	3	2	+	+	+			9
SSW	+	2	3	1	+	+	+			7
SW	+	2	1	1	+	+				4
WSW	+	1	1	+	+	+	+			2
W	+	1	1	+	+	+	+			3
WNW	+	1	1	1	+	+	+	+		3
NW	+	1	1	1	+	+	+	+		4
NNW	+	1	2	2	1	+	+	+		6
CALM	12									12
TOTAL	16	27	32	19	5	1	+	+	+	100

MOUNTS:

R OF THE DAY — PM HOUR ENDING AT	5	6	7	8	9	10	11	MID	NO. OF DAYS WITH
4	22	21	22	19	17	17	16	14	50
7	6	6	5	4	4	2	4	4	11
3	11	10	9	9	8	7	7	8	28
5	5	4	3	4	2	2	3	2	19
2	1	2	2	1	1	1	+	1	18
1	1	1	1	1	+	1	1	1	18
+	+	+		+	+	+	+	+	12
+	+		+						5
1	47	45	41	37	33	30	31	29	160

OF

	OVER	TOT
+	+	1
+	+	1
+	+	1
+	1	2
1	4	8
4	72	88
5	77	100

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10 0-3	4-7	8-10	WIND SPEED (M.P.H.) 0-3	4-12	13-24	25 & OVER	RELATIVE HUMIDITY (%) 0-29	30-49	50-69	70-79	80-89	90-100
00	55	13	32	24	60	15	1		2	10	11	33	44
01	55	13	32	29	56	14	1	+	2	10	8	31	50
02	53	12	34	31	54	14	1		2	9	8	27	54
03	52	13	35	33	52	14	1		1	9	8	25	57
04	51	13	36	34	51	14	1		1	8	8	23	60
05	47	15	38	34	51	14	1		1	8	8	23	60
06	43	17	41	30	54	15	1		1	8	9	25	57
07	42	17	41	18	63	18	1		1	11	16	38	34
08	40	19	41	9	63	27	1		3	20	30	27	20
09	38	21	41	5	59	35	1	+	7	36	29	17	12
10	37	23	40	3	57	39	1	+	11	48	21	11	8
11	37	23	40	2	55	41	2	1	16	52	15	9	7
12	37	22	40	2	53	43	2	1	20	51	13	8	6
13	36	23	41	2	53	43	2	2	25	47	12	9	5
14	36	21	42	3	55	41	2	3	27	43	12	9	6
15	36	21	44	2	59	37	1	4	27	43	12	9	6
16	36	19	45	4	62	33	1	3	25	40	15	10	7
17	36	19	45	8	66	25	1	1	19	38	21	14	8
18	38	18	44	13	68	18	1	1	12	35	25	19	9
19	42	18	40	17	68	14	1	+	5	25	28	27	15
20	47	17	36	19	65	15	1	+	4	16	25	35	20
21	51	15	35	20	64	15	1	+	4	12	19	39	26
22	53	15	33	20	64	16	1		3	11	16	40	31
23	54	14	32	22	63	15	1	+	3	10	13	37	37
AVG	44	17	39	16	59	24	1	1	9	25	16	23	27

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3

TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

[illegible]	0-4 M.P.H.						5-14 M.P.H.					
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
/100	+						+	1				
/ 95	+	7					+	36	3			
/ 90	+	15	15				2	74	106			
/ 85	1	10	30	4	+		6	54	253	55	2	
/ 80	1	6	17	25	35	7	8	42	135	186	196	21
/ 75	1	4	10	17	87	145	11	34	87	101	362	400
/ 70	2	5	8	11	27	79	16	39	64	69	149	313
/ 65	2	6	6	5	16	49	16	44	67	55	120	294
/ 60	2	6	7	5	10	41	13	48	68	52	102	218
/ 55	2	7	5	4	8	26	9	55	70	48	88	166
/ 50	1	5	7	5	8	17	5	43	84	46	71	107
/ 45	1	2	6	5	7	12	3	31	78	52	58	57
/ 40		2	4	4	6	5	2	18	50	42	37	33
/ 35	+		2	1	2	3		6	22	17	22	15
/ 30			1	1	1	1		2	12	8	9	6
/ 25			+	1	+	+		+	3	3	2	3
/ 20					+	+			1	+	+	
/ 15									1	1		
TAL	13	76	117	88	209	384	91	527	1103	733	1218	1633

[illegible]	15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
/100		+											1
/ 95		8	1						+				56
/ 90	1	28	83					+	2				327
/ 85	2	27	197	23	1		+	1	9	3			677
/ 80	4	25	117	71	25	2	1	1	15	9	2		949
/ 75	7	26	99	70	70	34	1	2	14	14	12	4	1611
/ 70	10	32	64	55	89	96	2	3	13	8	9	6	1172
/ 65	12	36	49	29	55	100	2	3	4	3	4	4	980
/ 60	10	44	40	22	30	43	1	4	3	1	1	2	772
/ 55	7	42	47	19	29	34	2	6	4	2	1	2	681
/ 50	4	32	45	22	23	31	1	4	5	2	1	3	570
/ 45	2	22	42	26	21	16	1	3	5	2	1	1	452
/ 40	1	13	24	18	14	13	+	2	1	1	2	1	291
/ 35	+	6	11	8	7	15		1	2	+	+	+	141
/ 30		4	6	2	4	6		1	1		+	+	64
/ 25		1	2	1	1	1			+	+	+		18
/ 20			1	+	+	+			+	+			4
/ 15				1						+			2
TAL	58	343	828	366	369	391	10	31	77	44	34	26	3767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY																								NO. OF DAYS WITH
	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	14	15	15	15	17	15	19	23	20	18	21	25	27	25	23	19	19	16	15	14	15	15	13	14	53
.01 IN	4	5	4	5	5	5	3	4	4	4	5	5	5	6	6	7	6	8	4	4	3	3	4	4	10
.02 TO .09 IN	5	5	6	6	7	7	7	7	9	9	8	9	11	11	11	10	10	9	7	6	6	5	6	6	29
.10 TO .24 IN	2	2	3	3	3	2	2	3	3	3	4	3	4	4	4	4	4	2	2	3	3	2	2	2	19
.25 TO .49 IN	+	1	1	1	1	1	2	1	1	1	1	1	2	1	2	2	1	+	1	1	+	1	1	1	15
.50 TO .99 IN	+	+	+	+	1	1	1	1	1	+	1	1	1	1	1	1	1	1	+	+	+	+	+	+	13
1.00 TO 1.99 IN			+	+	+		+		+	+		+	+	+	+	1	+	+	1						8
2.00 IN AND OVER													+					+					+		4
TOTAL	26	28	29	31	33	31	34	39	37	36	39	44	50	48	46	44	41	35	29	27	27	25	26	27	151

City Office Data

Table C data obtained from tipping bucket rain gage located at the Federal Bldg., Franklin and Fannin Streets(Houston City Office), at an elevation of 152 feet.

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET)									
	0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9900	OVER 9900	TOT
0 TO 1/8	+	+	+	+	+	+	+	+	+	1
3/16 TO 3/8	+	+	+	+	+	+	+	+	+	1
1/2 TO 3/4	+	+	+	+	+	+	+	+	+	1
1 TO 2 1/2		+	1	1	+	+	+	+	1	4
3 TO 6		+	1	2	1	1	1	1	5	10
7 TO 15		+	+	2	5	5	7	5	59	84
20 TO 30										
35 OR MORE							+			+
TOTAL	+	1	2	5	6	6	8	6	66	100

ES:

				TOTAL OBS
				1
+				56
2				327
9	3			677
5	9	2		949
4	14	12	4	1611
3	8	9	8	1172
4	3	4	4	980
3	1	1	2	772
4	2	1	2	681
5	2	1	3	570
5	2	1	1	452
1	1	2	1	291
2	+	+	+	141
1		+	+	64
+	+	+		18
+	+			4
	+			2
7	44	34	26	8767

y 10).
ctly

		NO OF DAYS
13	14	53
4	4	10
6	6	29
2	2	19
1	1	15
+	+	13
		8
+		4
26	27	151

K.,

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR)

DIRECTION	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 & OVER	TOTAL	AV SPEED
N	+	1	2	2	1	+	+	+	+	5	12.4
NNE	+	1	2	2	+	+	+		+	5	12.0
NE	+	1	2	2	+	+	+	+	+	6	11.2
ENE	+	1	3	2	+	+	+			7	11.0
E	+	1	2	1	+	+	+			6	10.2
ESE	+	2	3	2	1	+	+			8	10.8
SE	+	1	4	3	1	+	+	+		10	12.8
SSE	+	2	4	5	2	1	+	+		14	13.8
S	+	1	3	3	1	+	+			9	12.6
SSW	+	1	2	2	1	+	+			6	11.7
SW	+	1	2	1	+	+	+			4	9.8
WSW	+	1	1	1	+	+	+	+		3	9.8
W	+	1	1	+	+	+	+	+		2	9.3
WNW	+	1	1	1	+	+	+	+	+	4	11.2
NW	+	1	1	1	+	+	+	+	+	4	12.4
NNW	+	1	2	2	1	+	+	+	+	6	13.5
CALM	1									1	
TOTAL	6	18	36	28	10	2	+	+	+	100	11.8

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10			WIND SPEED (M P H)				RELATIVE HUMIDITY (%)					
	0-3	4-7	8-10	0-3	4-12	13-24	25- & OVER	0-29	30-49	50-69	70-79	80-89	90-100
00	51	13	35	7	66	26	1	+	4	11	10	32	43
01	51	13	36	9	66	25	1	+	3	10	9	29	49
02	50	13	37	9	66	23	1	+	3	9	9	25	54
03	48	14	38	10	65	24	1	+	3	9	8	23	58
04	48	13	39	11	65	23	1	+	2	8	8	22	60
05	44	16	40	10	66	23	1		2	8	8	21	62
06	41	14	45	10	65	24	1	+	2	8	8	22	61
07	39	14	47	9	63	26	1	+	2	9	14	33	42
08	33	19	48	7	54	37	2	+	4	16	27	28	26
09	27	24	49	6	46	46	3	1	7	33	26	18	15
10	26	25	49	5	45	46	4	1	13	46	19	11	9
11	24	27	48	4	43	48	5	3	19	50	12	9	7
12	24	27	50	4	40	50	6	4	24	47	11	8	6
13	24	26	50	4	39	51	6	6	29	41	11	7	6
14	24	27	49	4	37	54	5	7	30	40	10	7	6
15	27	25	49	3	36	55	6	8	28	40	11	7	5
16	31	22	47	2	35	58	5	7	25	41	12	8	6
17	36	18	45	2	37	57	3	5	21	40	17	11	7
18	40	16	44	2	42	54	2	2	15	37	20	16	9
19	42	17	41	3	51	45	1	1	9	25	24	25	15
20	47	15	38	3	59	36	1	1	7	17	22	31	22
21	49	15	36	4	65	30	1	+	6	14	16	36	28
22	51	14	35	5	66	28	1	+	5	12	13	36	34
23	53	13	34	6	66	27	1	+	5	11	11	35	39
AVG	39	18	43	6	53	38	3	2	11	24	14	21	28

HOUSTON, TEXAS
Int. Airport

B

TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
RH / TEMP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
9/ 95								+	1																1
4/ 90			1		+			3	44	2				+	10	1									62
9/ 85		1	8	7	1	+	1	11	335	239	27	1	+	2	118	121	15	+	+		1	2		+	849
4/ 80		1	18	42	34	6	+	15	196	379	443	60	1	3	48	151	146	18	1	1	1	2	5	+	1763
9/ 75	+	1	14	26	41	11	+	16	125	198	236	120	1	9	40	63	130	47	+	1	2	2	5	4	1144
4/ 70		1	6	14	23	20	1	20	85	105	217	220	3	15	37	52	88	83	1	4	3	2	3	4	1006
9/ 65		3	6	6	14	23	1	27	86	88	155	318	2	26	54	44	77	98	+	4	5	3	5	4	1042
4/ 60	+	3	10	9	11	30	1	39	85	66	143	398	3	27	62	45	57	84	+	8	7	4	6	4	1000
9/ 55		2	8	7	11	20	1	33	93	62	96	225	1	27	69	33	45	45	+	8	15	4	6	7	717
4/ 50		2	11	7	11	10	1	24	95	56	63	39	1	24	70	36	37	31	1	8	12	7	7	7	557
9/ 45		3	9	5	5	2	+	15	59	37	35	25	1	16	47	26	21	15	1	5	13	8	6	5	336
4/ 40		2	3	2	1	1	1	10	26	17	16	6	1	10	22	18	14	12	1	3	8	4	3	5	178
9/ 35			1	1	1			2	12	3	3	1	+	4	11	7	9	6	+	1	4	2	4	5	77
4/ 30					+			1	2	1	1	2		2	6	2	1	4		1	1	1	1	1	27
9/ 25				+	+				1	1	1	+		+	1	1	+	1				+			6
4/ 20															1	1	+					+	+		2
9/ 15																+	+					+	+		1
TOTAL	4	19	94	125	153	123	7	204	1213	1430	1474	1213	13	164	594	601	643	443	5	44	71	42	48	46	3767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole number, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C • OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY: A M HOUR ENDING AT												P M HOUR ENDING AT												NO OF DAYS WITH
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	10	11	10	12	12	16	17	19	25	22	22	21	18	17	15	18	18	16	16	14	15	13	12	11	41
.01 IN	4	3	3	4	4	4	4	4	4	5	4	3	4	4	4	4	4	3	3	4	3	4	4	4	9
.02 TO .09 IN	5	4	5	6	8	7	9	10	8	8	9	8	6	7	6	7	6	5	5	4	4	4	6	4	24
.10 TO .24 IN	2	2	3	3	3	3	2	4	3	3	3	3	3	2	3	2	2	1	1	2	2	2	1	2	18
.25 TO .49 IN	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	+	+	1	15
.50 TO .99 IN	+	+	1	+	+	1	+	1	1	1	+	1	+	+	+	1	+	+	+	+	+		+	+	13
1.00 TO 1.99 IN		+	+				+		+	+	+		+	+	+		+	+				+	+		7
2.00 IN AND OVER		+																							2
TOTAL	22	22	23	26	29	32	35	39	43	41	38	37	33	32	29	31	31	27	26	24	24	24	23	21	126

•City Office

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET): 0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OVER [illegible]	TOT
0 TO 1/8	.2	.3	+	+	+	+	+	+	.2	.7
3/16 TO 3/8	.1	.3	+	+	+	+	+	+	.2	.8
1/2 TO 3/4	+	.2	.1	+	.1	+	+	+	.2	.7
1 TO 2 1/2	+	.5	.3	.2	.2	.1	.1	.1	.3	1.7
3 TO 6		.2	.5	1.3	1.0	.9	.5	.4	2.7	7.2
7 TO 15		.1	.4	2.6	5.3	3.4	3.7	4.6	[illegible]	88.8
20 TO 30										
35 OR MORE									+	+
TOTAL	.5	1.5	1.5	4.5	6.6	4.1	4.4	5.2	72.9	100

GALVESTON, TEXAS
Municipal Airport

DITY OCCURRENCES:

MPH			25 MPH AND OVER						TOTAL OBS.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
									1
1									62
121	15	+	+		1	2		+	649
151	148	10	1	1	1	2	5	+	1763
63	130	47	+	1	2	2	5	4	1144
52	88	83	1	4	3	2	3	4	1006
44	77	98	+	4	5	3	5	4	1042
45	57	84	+	8	7	4	4	4	1000
33	45	45	+	8	15	4	6	7	717
36	37	31	1	8	12	7	7	7	557
26	21	15	1	5	13	8	6	5	336
18	14	12	1	3	8	4	3	5	178
7	9	6	+	1	4	2	4	5	77
2	1	4		1	1	1	1	1	27
1	+	1				+			6
1	+					+	+		2
+	+					+	+		1
601	643	443	5	44	71	42	48	46	3767

10-year total divided by 10).
djusted to make their sums
e than 0 but less than 0.5.

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR)										
	0 3	4 7	8 12	13 18	19 24	25 31	32 - 38	39 46	47 OVER	TOTAL	
N	.2	.8	1.7	2.0	1.3	.5	.1	+	+	6.7	15
NNE	.1	.6	1.7	1.8	1.0	.3	.1	+	+	5.6	14
NE	.2	.8	2.2	1.9	.6	.2	+	+		5.9	12
ENE	.1	.6	1.4	1.3	.5	.1	+			4.0	12
E	.2	.9	2.2	1.9	.6	.1	+	+		5.9	12
ESE	.1	1.1	3.7	3.3	.6	.1	+	+		8.9	12
SE	.2	1.7	6.0	4.0	.6	.1	+	+	+	12.3	11
SSE	.1	1.4	6.1	4.9	.6	+			+	13.2	12
S	.3	1.6	6.1	5.1	.9	.2	+	+	+	14.0	12
SSW	.1	.7	2.4	2.5	.7	.1	+			6.4	12
SW	.2	.7	1.5	1.1	.4	.1	+	+		4.1	11
WSW	.1	.5	.8	.3	.1	+	+			1.8	9
W	.1	.5	.7	.3	.1	+	+	+		1.8	10
WNW	.1	.4	.8	.5	.2	.1	+	+		2.1	12
NW	.1	.5	.9	.8	.5	.2	+	+	+	3.1	13
NNW	.1	.3	.7	.8	.7	.4	.1	+	+	3.0	16
CALM	1.1									1.1	
TOTAL	3.5	12.6	39.0	32.5	9.5	2.3	.5	.1	+	100	12

MOUNTS:

R OF THE DAY									NO OF DAYS WITH
P M HOUR ENDING AT									
	5	6	7	8	9	10	11	MID	
8	10	16	16	14	15	13	12	11	41
4	4	3	3	4	3	4	4	4	9
7	6	5	5	4	4	4	6	4	24
2	2	1	1	2	2	2	1	2	18
1	1	1	1	1	1	+	+	1	15
1	+	+	+	+	+		+	+	13
	+	+				+	+		7
									2
1	31	27	26	24	24	24	23	21	120

)F

[illegible]	OVER [illegible]	TOT
+	.2	.7
+	.2	.8
+	.2	.7
.1	.3	1.7
.6	2.7	7.2
[illegible]	[illegible]	[illegible]
	+	+
.2	72.5	100

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10			WIND SPEED (M.P.H.)				RELATIVE HUMIDITY (%)					
	0-3	4-7	8-10	0-3	4-12	12-24	25-& OVER	0-29	30-49	50-69	70-79	80-89	90-100
00	49	18	33	4	57	36	3	+	2	14	25	31	28
01	48	19	33	5	56	36	3	+	2	14	23	32	29
02	47	19	34	6	56	35	3	+	2	13	23	32	30
03	45	19	36	6	58	34	3	+	1	13	22	33	31
04	45	19	36	6	58	33	3	+	1	12	22	33	33
05	40	22	38	6	59	32	3	+	1	11	19	35	34
06	35	23	42	6	58	33	3		1	11	20	35	34
07	33	22	44	6	55	36	3		1	12	25	33	29
08	33	24	44	4	51	42	3	+	2	18	28	30	23
09	31	25	44	2	48	46	3	+	4	25	29	25	17
10	31	26	44	2	45	50	3	+	6	31	29	22	12
11	32	25	43	2	43	53	3	+	7	35	28	20	9
12	33	24	43	1	41	55	3	1	9	36	27	19	8
13	34	24	42	1	40	56	3	1	10	37	26	18	8
14	35	23	42	1	40	56	3	1	11	38	24	19	7
15	37	20	43	1	42	55	3	1	12	36	25	19	8
16	38	19	43	1	45	51	3	1	10	35	24	19	10
17	38	18	46	2	51	45	3	1	9	31	25	20	14
18	37	19	44	2	54	41	2	+	7	27	27	21	17
19	39	20	41	4	57	37	3	+	5	22	27	25	21
20	42	20	38	4	57	36	2	+	4	20	26	28	22
21	45	20	34	4	58	35	2	+	3	18	26	29	24
22	47	20	33	4	57	37	3		3	16	26	29	26
23	48	19	33	5	56	36	3	+	3	16	25	30	27
AVG	39	21	40	3	52	42	3	+	5	22	25	26	21

TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

[illegible]	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL [illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
100							+																		+
95							2	1					+	+											2
90	1						4	2					1	+											7
85	1	1	+				10	12	3				1	+											29
80	5	3	3				29	26	57	+			1	1	1										126
75	11	8	17	6	1		46	32	254	33	2		2	1	4	+									416
70	15	22	30	44	74	12	38	57	475	162	65	5	1	1	13	2	+								1016
65	16	39	62	123	327	69	33	81	546	322	262	35	1	5	27	5	2	1					+		1956
60	17	65	117	216	348	108	19	81	446	408	301	61	1	6	29	10	5	4			2	+	+	1	2244
55	19	81	137	195	295	137	17	41	225	242	200	84	1	5	19	11	13	12			1	+	1	1	1736
50	13	62	129	102	187	89	8	13	69	57	71	26	+	1	9	2	2	3				+	+	+	843
45	5	30	71	56	77	28	3	5	16	15	16	5			1	+	+	1			+				328
40	1	9	14	13	13	2	+	3	1	1	2					+									59
35	+	1	2	+	1			+	+		+														4
TOTAL	104	321	581	756	1321	446	208	354	2091	1240	920	217	8	19	103	31	23	20			2	1	1	2	8767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY																								NO OF DAYS WITH
	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	11	12	12	13	12	14	11	12	11	10	9	8	7	7	6	6	7	7	7	7	8	7	7	10	30
.01 IN	3	4	3	4	4	3	3	2	3	4	2	1	1	1	3	2	2	1	2	3	2	3	3	3	6
.02 TO .09 IN	3	4	6	6	5	4	5	4	4	3	2	2	2	2	2	3	3	4	[illegible]	4	4	3	4	4	14
.10 TO .24 IN	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	+	1	1	+	1	1	1	1	10
.25 TO .49 IN	+	+	+	+	+		+	+	+	+	+	+	1	+		+	+	+	+	+		+		+	6
.50 TO .99 IN				+						+						+						+			4
1.00 TO 1.99 IN															+										1
2.00 IN AND OVER																									+
TOTAL	18	21	23	24	22	22	20	20	19	17	14	13	11	11	12	12	12	13	13	14	15	15	14	17	70

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET)									
	0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9900	OVER 9900	TOT
0 TO 1/8	+	+	+	+					+	1
3/16 TO 3/8	+	+	+		+				+	+
1/2 TO 3/4	+	+	+	+	+				+	1
1 TO 2 1/2	+	+	1	1	+	+	+	+	1	4
3 TO 6		+	+	3	3	+	+	+	7	13
7 TO 15			+	2	12	5	4	1	39	62
20 TO 30				+	1	1	1	+	9	12
35 OR MORE				+	+	+	1	+	6	7
TOTAL	+	1	1	6	15	7	5	2	62	100

A

ITY OCCURRENCES:

.P.H.			25 M.P.H. AND OVER						TOTAL OBS.
									+
									2
									7
									29
									126
+									416
2	+								1016
5	2	1					+		1956
10	5	4			2	+	+		12244
11	13	12			1	+	1		11736
2	2	3				+	+	+	843
+	+	1			+				328
+									59
									4
31	23	20			2	1	1		28767

ar total divided by 10).
ake their sums exactly
ess than 0.5.

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR) 0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 AND OVER	TOTAL	AV. SPEED
N	3	3	1	+						7	4.
NNE	3	3	+	+						7	4.
NE	4	4	+	+	+					8	4.
ENE	2	2	+	+	+					4	4.
E	2	1	+	+	+					3	4.
ESE	1	1	+	+						2	4.
SE	1	1	+	+	+					2	5.
SSE	+	1	1	+	+	+	+			2	7.
S	1	2	2	1	+	+				5	7.
SSW	1	3	3	1	+	+	+			8	8.
SW	1	3	3	1	+	+				8	7.
WSW	1	3	3	1	+	+				8	8.
W	1	3	3	1	+					8	7.
WNW	1	3	5	1	+					10	8.
NW	1	3	4	1	+	+				8	7.
NNW	1	3	2	+	+					7	6.
CALM	6									6	
TOTAL	28	38	28	6	+	+	+			100	6.

OUNTS:

OF THE DAY — HOUR ENDING AT 5	6	7	8	9	10	11	MID	NO. OF DAYS WITH
7	7	7	7	8	7	7	10	30
2	1	2	3	2	3	3	3	6
3	4	4	4	4	3	4	4	14
+	1	1	+	1	1	1	1	10
+	+	+	+		+		+	6
					+			4
								1
								+
12	13	13	14	15	15	14	17	70

F

	OVER ...	TOT
	+	1
	+	+
	+	1
+	1	4
+	7	13
1	39	62
+	9	12
+	6	7
2	62	100

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10: 0-3	4-7	8-10	WIND SPEED (M.P.H.): 0-3	4-12	13-24	25 & OVER	RELATIVE HUMIDITY (%): 0-29	30-49	50-69	70-79	80-89	90-100
00	40	8	52	48	50	2		1	4	11	23	47	14
01	38	7	55	49	49	2		1	5	12	21	45	17
02	36	7	57	49	49	2		1	5	11	20	44	19
03	36	6	58	49	49	2	+	1	5	12	19	43	20
04	35	6	59	49	49	2		1	5	11	20	42	21
05	35	6	59	49	49	2	+	1	5	12	20	41	20
06	33	8	59	48	50	2	+	2	6	13	24	39	17
07	32	10	58	45	53	2		2	7	20	30	31	10
08	37	12	51	34	62	4	+	3	8	31	34	19	4
09	46	12	42	19	76	5	+	5	10	44	29	10	2
10	54	13	34	10	81	9	+	8	12	56	19	5	1
11	58	13	28	3	83	14	+	9	13	62	13	3	+
12	60	14	26	1	80	18	+	9	14	65	10	2	1
13	62	14	24	1	77	22	+	9	14	67	8	1	1
14	62	14	24	1	79	20	+	8	14	67	8	2	1
15	61	14	24	1	83	16	+	7	13	67	11	2	1
16	61	13	25	2	88	10		5	11	61	18	4	1
17	60	13	27	6	88	5	+	4	8	46	32	9	1
18	58	14	28	16	81	3		3	6	25	45	19	2
19	55	13	32	23	74	2	+	2	6	17	38	34	3
20	52	12	36	30	68	2	+	1	5	15	33	41	5
21	49	11	40	38	60	2	+	1	5	13	29	45	6
22	46	10	44	42	57	2	+	1	4	13	28	47	9
23	43	9	48	46	52	2		1	4	12	24	47	12
AVG	48	11	41	28	66	6	+	4	8	32	23	26	8

B

A TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
109/105							+																		+
104/100	+						1																		1
99/ 95	1						2	+					1												4
94/ 90	2						3	2					+	+											7
89/ 85	4	2	+				10	9	2				1	1	+										28
84/ 80	9	4	3	+			26	21	45	+			1	3	5										117
79/ 75	11	7	17	2	+		40	40	206	12			3	4	37	+					+				380
74/ 70	15	13	44	36	25	1	42	54	393	143	25	1	4	8	66	11	+		1		+				881
69/ 65	14	27	68	132	223	22	47	75	390	315	220	19	9	13	61	17	2		1	1	1				1654
64/ 60	13	39	92	174	444	141	46	87	302	323	346	73	8	17	51	19	6	3	2	3	3	1	+		2193
59/ 55	11	39	90	156	371	201	33	81	177	208	294	143	9	17	28	13	10	14	2	4	4	1	1	1	1704
54/ 50	5	31	71	76	185	164	17	60	94	75	118	105	5	13	13	5	5	7	1	2	3	1	1	1	1054
49/ 45	3	13	44	39	73	59	9	28	50	30	40	28	1	5	3	1	2	2	+	1	+				428
44/ 40	1	6	13	15	18	11	1	7	12	10	9	4			+	+	1	+							107
39/ 35		1	2	2	1	1		2	1	1	+	+													10
34/ 30			+				1		+																+
TOTAL	88	182	444	631	1340	601	277	466	1670	1114	1051	372	42	80	263	66	27	25	6	11	11	2	2	2	8767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY — A M HOUR ENDING AT												P M HOUR ENDING AT												NO. OF DAYS WITH
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	8	10	11	11	15	14	13	13	11	8	9	8	6	7	6	7	6	8	8	8	7	7	7	8	27
.01 IN	2	3	3	3	2	3	3	3	1	2	3	1	2	2	3	2	2	1	2	3	2	2	2	2	4
.02 TO .09 IN	4	4	3	4	4	4	4	3	3	3	2	3	4	3	3	3	3	3	4	3	4	5	5	4	10
.10 TO .24 IN	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	+	1	1	1	1	7
.25 TO .49 IN	+	+	1	1	1	+	+	+	+	+	1	+	+	1	+	+	+	+		+	1	+	+	1	6
.50 TO .99 IN		+		+				+	+		+	+											+		5
1.00 TO 1.99 IN													+												1
2.00 IN AND OVER																									1
TOTAL	17	18	20	19	23	22	21	19	17	14	15	14	13	13	13	14	13	14	14	14	14	15	16	16	61

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET) 0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9500	OVER 9500	TOT
0 TO 1/8	1	+	+		+				+	1
3/16 TO 3/8	+	1	+	+	+		+	+	+	1
1/2 TO 3/4		+	1	+	+	+	+	+	1	2
1 TO 2 1/2		+	1	3	2	+	+	+	6	13
3 TO 6		+	+	3	4	1	1	+	17	26
7 TO 15	+		+	1	3	3	3	1	37	48
20 TO 30				+	+	+	+	+	5	6
35 OR MORE					+	+	+	+	2	2
TOTAL	1	1	2	7	10	4	4	2	68	100

LOS ANGELES, CAL.
Int. Airport

IDITY OCCURRENCES:

	… M.P.H.			25 M.P.H. AND OVER						TOTAL OBS.
										+
										1
										4
										7
+										28
3										117
7	+					+				380
5	11	+		1		+				881
1	17	2		1	1	1				1654
1	19	6	3	2	3	3	1	+		2193
8	13	10	14	2	4	4	1	1	1	1704
3	5	5	7	1	2	3	1	1	1	1054
3	1	2	2	+	1	+				428
+	+	1	+							107
										10
										+
3	66	27	25	6	11	11	2	2	2	8767

-year total divided by 10).
) make their sums exactly
t less than 0.5.

PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

B

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR)									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 & OVER	TOTAL
N	1	1	+	+	+	+	+			2
NNE	+	1	1	+	+	+				2
NE	1	2	1	+	+					4
ENE	1	3	1	+	+	+				5
E	2	3	1	+	+					6
ESE	1	2	1	+	+					4
SE	1	2	1	+	+	+				4
SSE	1	1	+	+	+	+	+			2
S	1	1	+	+	+	+				2
SSW	1	1	+	+	+	+				2
SW	1	2	3	1	+					6
WSW	1	5	10	4	+	+	+			20
W	1	5	7	4	+	+	+			17
WNW	1	2	1	+	+	+				3
NW	1	1	+	+	+	+	+			2
NNW	+	1	+	+	+	+	+			2
CALM	13									13
TOTAL	28	33	27	11	1	+	+			100

AMOUNTS:

UR OF THE DAY									NO. OF DAYS WITH
P.M. HOUR ENDING AT									
4	5	6	7	8	9	10	11	MID	
7	6	8	8	8	7	7	7	8	27
2	2	1	2	3	2	2	2	2	4
3	3	3	4	3	4	5	5	4	10
1	1	1	1	+	1	1	1	1	7
+	+	+		+	1	+	+	1	6
							+		5
									1
									1
14	13	14	14	14	14	15	16	16	61

OF

	OVER	TOT
	+	1
+	+	1
+	1	2
+	6	13
+	17	26
1	37	48
+	5	6
+	7	2
7	68	100

PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

E

HOUR OF DAY	CLOUDS SCALE 0-10			WIND SPEED (M.P.H.)				RELATIVE HUMIDITY (%)					
	0-3	4-7	8-10	0-3	4-12	13-24	25-& OVER	0-29	30-49	50-69	70-79	80-89	90-100
00	51	9	41	43	54	3	+	2	6	9	18	47	18
01	49	7	44	46	51	3	+	2	6	8	16	47	21
02	47	8	45	47	51	3	+	2	6	8	14	45	24
03	45	8	48	46	51	3	+	2	6	8	14	43	26
04	43	8	50	48	50	2	+	2	7	9	14	43	26
05	40	8	52	48	50	2	+	2	7	9	15	42	25
06	37	8	54	46	51	2	+	2	7	10	17	41	23
07	35	9	56	43	54	3	+	3	8	15	26	33	16
08	39	11	51	36	61	3	+	5	10	25	30	21	8
09	44	12	44	27	69	4	+	8	12	40	25	11	4
10	50	12	38	16	77	6	+	11	12	50	17	7	2
11	55	12	33	10	76	13	+	13	13	56	13	4	2
12	58	13	29	5	70	24	1	12	15	58	11	3	1
13	61	12	27	3	61	36	1	10	14	61	11	3	1
14	61	12	27	1	57	41	1	8	13	61	13	3	1
15	61	13	26	1	57	41	1	7	12	58	17	5	2
16	59	12	29	2	60	36	1	5	10	50	25	8	2
17	57	13	30	5	69	26	+	3	7	35	35	17	3
18	55	12	33	11	74	15	+	2	5	22	36	29	5
19	56	11	33	16	75	8	+	3	5	17	31	37	8
20	57	9	34	25	69	6	+	2	5	14	28	40	11
21	56	9	35	32	63	5	+	2	6	12	25	42	13
22	55	9	37	36	60	3	+	2	6	10	24	44	14
23	52	9	39	40	57	3	+	2	6	9	21	46	15
AVG	51	10	39	26	61	12	+	5	8	27	21	20	11

LOS ANGELES, CAL.
Int. Airport

TEMPERATURE AND WIND SPEED—RELATIVE HUMIDITY OCCURRENCES:

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS
REL. HUMID. / TEMP (F)	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	
4/100							+	+																	1
9/ 95	1						2	1					2	+											6
4/ 90	1	1					10	8					3	1											23
9/ 85	1	3	+				11	30	2				3	4	+										54
4/ 80	2	9	2				14	69	14				3	12	1										126
9/ 75	2	12	10	+			10	100	58	+			3	12	4				+						211
4/ 70	1	19	45	7	+		6	98	164	8	+		3	13	9	+					+	+			373
9/ 65	1	22	88	32	11	2	6	75	242	57	13	1	3	9	17	2	1	+	+	+	+	+	+		581
4/ 60	2	15	103	113	99	30	4	46	234	172	105	31	3	8	22	7	7	2	+		+	+	+		1001
9/ 55	1	13	81	135	191	113	3	34	173	174	204	85	2	13	35	17	26	11		+	2	1	1	2	1316
4/ 50	+	9	54	90	170	164	2	29	127	145	185	120	2	14	38	33	49	27		1	3	3	5	3	1274
9/ 45	+	6	44	65	135	167	3	18	93	140	216	139	3	19	49	50	78	30	+	2	2	4	7	2	1271
4/ 40	+	3	24	57	147	210	1	9	56	102	224	171	3	13	40	39	87	41	+	1	2	1	6	2	1238
9/ 35		2	10	23	87	205		3	22	42	112	138	+	6	33	22	35	28	+	+	2	1	2	1	772
4/ 30			4	10	32	117	+	1	10	13	39	62	1	4	17	8	13	10	+	1	2		+		343
9/ 25		1	2	6	12	30	+	3	10	7	11	10	+	5	8	5	8	2		+	+	1	2	+	123
4/ 20		1	3	1	3	1		2	6	2	1	+	+	6	11	2	3	+		+	+		+		40
9/ 15			1	1	+	+		+	4	1	+			1	2										10
4/ 10			1	+				+	3		+			+	+										4
9/ 05			+						1	+															1
TOTAL	12	116	469	536	886	1036	73	520	1216	862	1108	758	33	138	286	185	307	150	1	5	19	11	23	6	8767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY — A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												NO. OF DAYS WITH
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	38	36	36	38	45	46	47	49	43	42	46	47	45	48	47	43	42	39	40	36	34	32	38	36	45
.01 IN	14	15	16	16	14	14	15	17	16	16	14	13	17	15	17	17	16	15	14	14	16	18	15	15	15
.02 TO .09 IN	21	25	25	26	23	24	23	22	24	22	19	22	25	25	25	26	24	24	23	24	23	25	20	19	48
.10 TO .24 IN	3	3	4	3	3	3	4	3	4	3	4	3	2	4	4	4	4	3	4	4	3	2	2	3	41
.25 TO .49 IN	+	+	+	+			+	+	+		+		+	1	+	+	+	1		+	+	+			32
.50 TO .99 IN																									17
1.00 TO 1.99 IN																									5
2.00 IN AND OVER																									+
TOTAL	76	78	81	84	84	87	89	91	87	83	83	85	89	92	93	89	85	82	81	78	76	77	75	73	201

D PERCENTAGE FREQUENCIES OF CEILING—VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET) 0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9500	OVER 9500	TOT
0 TO 1/8	1	+	+	+	+	+	+	+	+	1
3/16 TO 3/8	+	+	+	+	+	+	+	+	+	1
1/2 TO 3/4	+	+	+	+	+	+	+	+	+	1
1 TO 2 1/2		+	+	1	+	+	+	+	1	3
3 TO 6		+	+	1	2	1	2	1	4	11
7 TO 15	+	+	+	1	4	4	12	10	27	58
20 TO 30				+	+	1	4	4	8	16
35 OR MORE				+	+	+	+	1	7	9
TOTAL	1	1	1	2	7	7	18	16	48	100

ES:

... AND OVER				TOTAL OBS
				1
				6
				23
				54
				126
				211
+	+			373
+	+	+		581
+	+	+		1001
2	1	1	1	1316
3	3	5	3	1274
2	4	7	2	1271
2	1	6	2	1238
2	1	2	1	772
2		+		343
+	1	2	+	123
+		+		40
				10
				4
				1
.3	11	23		68767

y 10).
ctly

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR) 0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 OVER	TOTAL	AV SPEED
N	1	1	+	+	+					3	5.1
NNE	+	+	+	+						1	4.0
NE	1	+	+	+	+					1	4.1
ENE	+	+	+	+	+	+				1	7.4
E	1	1	1	1	+	+	+			4	10.1
ESE	1	3	4	4	1	+	+			13	10.8
SE	1	2	2	1	+	+				6	7.9
SSE	1	1	1	1	+	+	+			4	8.0
S	1	1	2	2	1	+	+	+		7	11.3
SSW	+	1	2	2	1	+	+	+	+	7	13.0
SW	1	1	1	1	+	+				4	8.3
WSW	1	1	1	+	+	+				3	7.4
W	1	2	1	+	+	+				4	5.8
WNW	2	4	4	1	+	+				11	7.6
NW	3	5	5	1	+	+				14	7.3
NNW	1	2	2	1	+					6	7.3
CALM	11									11	
TOTAL	28	27	25	16	4	1	+	+	+	100	7.7

...	M-O	NO OF DAYS WITH
38	36	45
15	15	15
20	19	48
2	3	41
		32
		17
		5
		+
75	73	201

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10: 0-3	4-7	8-10	WIND SPEED (M.P.H.): 0-3	4-12	13-24	25-& OVER	RELATIVE HUMIDITY (%): 0-29	30-49	50-69	70-79	80-89	90-100
00	37	9	54	36	50	13	1	+	1	12	22	36	29
01	35	9	56	39	47	13	1	+	1	9	19	39	32
02	33	9	59	41	45	13	+	+	1	7	17	39	36
03	30	8	61	42	45	13	+	+	1	6	15	40	39
04	27	9	64	44	42	13	1	+	1	5	13	38	43
05	23	9	68	43	43	13	1	+	1	4	12	39	44
06	20	9	72	42	44	14	1	+	1	5	14	39	42
07	17	9	74	38	47	14	1	+	1	7	20	37	35
08	17	9	75	32	51	16	1	+	1	14	26	31	27
09	18	10	72	27	54	17	1	+	2	27	25	25	20
10	20	10	70	23	56	20	1	1	5	37	22	22	14
11	23	10	67	20	57	22	1	2	10	41	19	18	10
12	25	10	65	16	58	24	1	2	17	41	16	16	8
13	25	12	63	14	60	25	1	3	23	38	14	14	8
14	26	12	62	13	60	26	1	4	27	36	13	13	8
15	27	11	62	14	56	29	1	5	28	33	13	13	8
16	27	11	62	15	55	29	1	5	28	32	13	14	9
17	28	12	60	16	55	28	1	3	23	33	13	17	11
18	30	12	58	18	54	27	1	2	18	33	15	18	13
19	31	12	56	21	56	22	1	1	11	34	17	20	17
20	34	11	55	23	58	19	1	1	6	31	21	23	19
21	35	12	53	25	57	17	+	+	4	25	25	25	21
22	36	10	53	28	55	16	1	+	3	20	26	28	23
23	36	10	53	33	52	15	1	+	2	15	25	33	25
AVG	28	10	62	28	52	19	1	1	9	23	18	27	22

PORTLAND, OREG
Int. Airport

A TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
REL. HUMID. / TEMP. (°F)	UNDER 30%	30-49%	50-69%	70-79%	80-89%	90-100%	UNDER 30%	30-49%	50-69%	70-79%	80-89%	90-100%	UNDER 30%	30-49%	50-69%	70-79%	80-89%	90-100%	UNDER 30%	30-49%	50-69%	70-79%	80-89%	90-100%	
99/ 95							1						1												2
94/ 90							3	2					2	+											6
89/ 85	+	1					5	12					3	4											24
84/ 80	1	2	+				5	34	2				4	14	1				+	+					62
79/ 75	+	5	2				5	66	15				3	23	4										123
74/ 70	1	9	12	+			4	85	86	1			3	34	23	+			+	1	+				258
69/ 65	1	7	28	8	1		+	73	199	26	4	+	2	29	57	7	1		+	1	2	+	+		448
64/ 60	+	5	42	31	23	6	2	43	230	124	67	19	2	22	72	32	15	6	+	+	4	2	1	+	750
59/ 55	+	5	31	36	61	66	3	33	173	169	222	201	1	20	73	54	57	47		1	6	5	5	4	1272
54/ 50	+	5	26	28	51	117	2	34	127	138	245	327	2	18	65	64	89	84		3	9	8	12	9	1462
49/ 45	+	3	27	29	60	107	+	19	104	131	237	291	2	14	68	74	117	99		1	11	13	25	17	1445
44/ 40		1	17	28	64	135	1	15	74	107	224	335	1	11	38	62	145	97		+	3	12	27	13	1408
39/ 35			8	15	40	125	1	11	40	61	142	256	+	8	17	18	63	85		+	+	2	10	12	914
34/ 30			4	9	16	92	1	11	21	21	49	135	+	5	12	8	12	27			1	1	1	2	427
29/ 25			2	3	6	16	+	6	14	7	10	17	+	4	6	4	4	5		+	1	+	+	+	104
24/ 20			+	1	1	2	+	3	7	4	4	2		2	5	2	2	1		1	1	+			39
19/ 15			1	+	+			2	6	3	1			1	2	1				+	1				20
14/ 10				+				+	1	1	1				+										3
TOTAL	4	43	200	188	324	666	35	649	1098	792	1205	1585	25	207	442	325	505	450	1	8	38	42	81	57	8767

In Table A, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

DATA NOT AVAILABLE

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET) 0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9500	OVER 9500	TOT.
0 TO 1/8	1	1	+	+	+	+	+	+	+	2
3/16 TO 3/8	+	+	+	+	+	+	+	+	+	1
1/2 TO 3/4	+	+	+	+	+	+	+	+	+	1
1 TO 2 1/2	+	+	1	1	1	+	+	+	1	4
3 TO 6		+	+	1	2	1	1	1	3	9
7 TO 15		+	+	2	7	6	9	8	26	58
20 TO 30			+	+	1	1	2	3	10	17
35 OR MORE				+	+	+	+	1	6	8
TOTAL	1	2	2	4	10	9	13	13	47	100

SEATTLE, WASHINGTON
Seattle-Tacoma Airp

ƷMIDITY OCCURRENCES:

15-24 M.P.H.				25 M.P.H. AND OVER						TOTAL OBS.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
										2
										6
										24
1				+	+					62
4										123
23	+			+	1	+				258
57	7	1		+	1	2	+	+		448
72	32	15	6	+	+	4	2	1	+	750
73	54	57	47		1	6	5	5	4	1272
65	64	89	84		3	9	8	12	9	1462
68	74	117	99		1	11	13	25	17	1445
30	62	149	97		+	3	12	27	13	1408
17	16	63	85		+	+	2	10	12	914
12	8	12	27			1	1	1	2	427
6	4	4	5		+	1	+	+	+	104
5	2	2	1		1	1	+			39
2	1				+	1				20
+										3
442	325	505	450	1	8	38	42	81	57	8767

(10-year total divided by 10).
ɟd to make their sums exactly
) but less than 0.5.

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR)								
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 OVER
N	+	1	3	3	+	+	+		
NNE	+	1	3	3	+	+	+		
NE	+	1	3	2	+	+			
ENE	+	1	1	+	+	+			
E	+	1	1	1	+	+			
ESE	+	1	2	1	+	+	+		
SE	+	2	3	1	+	+			
SSE	+	1	2	1	+	+			
S	+	2	4	3	1	+	+	+	
SSW	+	1	3	4	2	1	+	+	
SW	+	1	4	5	2	1	+	+	
WSW	+	1	2	1	+	+	+	+	+
W	+	1	1	1	+	+	+		
WNW	+	1	1	+	+				
NW	+	1	1	+	+	+	+	+	
NNW	+	+	1	1	+	+	+		
CALM	10								
TOTAL	13	16	35	26	8	2	+	+	+

ɪ AMOUNTS:

ƎS OF

[illegible]	[illegible]	OVER [illegible]	TOT.
+	+	+	2
+	+	+	1
+	+	+	1
+	+	1	4
1	1	3	9
9	8	26	58
2	3	10	17
+	1	6	8
13	13	47	100

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10			WIND SPEED (M.P.H.)				RELATIVE HUMIDITY (				
	0-3	4-7	8-10	0-3	4-12	13-24	25-& OVER	0-29	30-49	50-69	70-79	80-89
00	33	10	57	14	53	31	2	+	2	9	16	33
01	32	9	59	16	54	28	2	+	2	7	13	33
02	29	9	61	17	55	27	2	+	1	6	11	31
03	27	10	63	17	55	26	2	+	1	5	10	30
04	24	10	66	19	55	24	2	+	1	4	9	28
05	20	10	70	20	54	24	2	+	1	3	8	28
06	18	11	71	19	55	25	1	+	1	4	10	30
07	16	10	74	18	55	26	2	+	1	7	14	33
08	16	9	74	17	53	28	2	+	2	12	20	30
09	17	10	73	15	52	30	3	+	3	20	22	26
10	19	11	70	13	50	33	3	+	5	29	22	22
11	20	13	67	11	48	37	4	1	9	36	20	[illegible]
12	21	15	64	10	48	38	4	1	13	40	17	[illegible]
13	22	14	64	9	46	42	4	2	19	39	15	[illegible]
14	23	14	63	8	45	42	4	2	23	37	13	[illegible]
15	24	14	62	9	46	42	3	3	24	34	13	[illegible]
16	25	13	62	10	46	41	3	3	23	32	14	[illegible]
17	26	14	60	11	47	40	2	2	20	30	14	[illegible]
18	27	14	60	11	49	37	3	1	17	29	15	[illegible]
19	28	14	58	12	50	36	2	1	11	29	16	[illegible]
20	31	14	56	13	49	36	2	+	6	25	19	[illegible]
21	32	13	55	12	51	36	2	+	4	21	20	[illegible]
22	33	11	55	12	50	36	2	+	3	16	20	[illegible]
23	33	11	56	12	52	33	2	+	3	12	19	[illegible]
AVG	25	12	63	13	51	33	3	1	8	20	15	[illegible]

SEATTLE, WASHINGTON
Seattle-Tacoma Airport

TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES:

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
REL. HUMID / TEMP (°F)	Under 30	30-49%	50-69%	70-79%	80-89%	90-100%	Under 30	30-49%	50-69%	70-79%	80-89%	90-100%	Under 30	30-49%	50-69%	70-79%	80-89%	90-100%	Under 30	30-49%	50-69%	70-79%	80-89%	90-100%	
/105							+																		+
/100							1	1					+	1											2
/ 95	+						3	12	1				2	4						+					21
/ 90	+	4	1				2	40	12				1	16	4										79
/ 85	+	8	8	+			5	69	63	2			4	24	16	+			+	+	+				200
/ 80	1	14	22	7	1		7	96	129	33	5	+	7	30	21	7	+		1	1	+	+			383
/ 75	1	13	30	27	23	12	9	106	147	79	58	23	8	35	24	8	6	4	1	1	1	+	+	+	615
/ 70	1	12	34	31	51	53	12	86	169	88	103	65	9	26	26	10	9	8	1	1	1	+	1	1	819
/ 65	1	9	36	36	51	44	12	78	152	92	109	83	9	34	32	10	11	12	1	2	1	+	1	1	814
/ 60	1	11	30	35	45	44	12	80	133	79	87	82	9	36	32	8	12	14	1	2	1	1	+	3	755
/ 55	1	10	29	28	37	34	10	83	124	67	66	80	8	33	37	11	12	19	1	3	1	1	1	1	697
/ 50	1	9	31	24	37	30	6	81	136	61	73	83	3	36	32	12	13	19	+	3	1	+	1	1	692
/ 45	1	9	33	28	30	29	5	70	133	69	68	73	3	47	47	12	13	21	1	3	4	1	1	1	701
/ 40	+	9	35	28	30	32	2	81	171	77	57	74	2	52	65	19	18	21	1	5	3	+	1	1	784
/ 35		8	42	33	31	25	1	62	209	82	70	82	2	49	69	17	16	35	+	6	4	1	1	2	846
/ 30	+	7	38	22	19	19	1	57	172	52	41	45	1	52	60	10	9	22	+	5	3	+	+	1	637
/ 25		2	17	11	8	5	1	38	113	31	16	12	2	36	51	6	2	4	+	3	3		+	1	360
/ 20	+	3	11	5	2	+	1	27	70	12	6	1	1	21	29	3	4	3	+	2	1	+	+	1	202
/ 15		2	8	3	1	1		12	32	6	2	+	+	15	19	2	3	+		3	1	+	+		109
/ 10		1	4	+	+	+		4	11	1	1	+		4	9	+	1			+	+	+	+		38
/ 05			+	+	+			1	5	1				2	2		+								11
/ 00					+				1	+				+	+										2
TOTAL	8	131	406	320	366	327	88	1082	1984	832	763	723	69	552	575	132	129	181	7	39	27	6	8	15	8767

In Tables A and C, occurrences are for the average year (10-year total divided by 10). Values are rounded to the nearest whole, but not adjusted to make their sums exactly equal to column or row totals. "+" indicates more than 0 but less than 0.5.

C OCCURRENCES OF PRECIPITATION AMOUNTS:

INTENSITIES	FREQUENCY OF OCCURRENCE FOR EACH HOUR OF THE DAY — A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												NO. OF DAYS WITH
	1	2	3	4	5	6	7	8	9	10	11	NOON	1	2	3	4	5	6	7	8	9	10	11	MID	
TRACE	28	27	28	26	31	28	29	32	33	29	30	30	29	32	30	28	27	26	27	28	27	27	29	29	60
.01 IN	7	8	8	9	6	7	9	8	8	8	7	8	6	6	8	8	7	7	9	6	8	9	8	8	12
.02 TO .09 IN	17	16	17	16	15	15	14	15	14	14	14	13	14	14	15	14	14	14	15	15	15	15	16	15	33
.10 TO .24 IN	4	5	5	5	5	5	5	4	4	5	4	4	5	3	3	4	4	3	3	5	3	4	5	5	27
.25 TO .49 IN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	+	1	1	1	1	1	1	1	21
.50 TO .99 IN	+	+	+	+	1	+	+	+	+	+	+			+	1	+	+	+	+	+	1	+	+	+	20
1.00 TO 1.99 IN				+											+	+					+		+		9
2.00 IN AND OVER																									1
TOTAL	57	56	58	57	58	56	58	60	60	58	56	56	55	57	57	55	52	51	55	55	55	57	59	59	182

D PERCENTAGE FREQUENCIES OF CEILING–VISIBILITY:

VISIBILITY (MILES)	CEILING (FEET) 0	100-200	300-400	500-900	1000-1900	2000-2900	3000-4900	5000-9500	OVER 9500	TOT
0 TO 1/8	+	+	+	+			+		+	+
3/16 TO 3/8	+	+	+	+	+	+	+	+	+	+
1/2 TO 3/4	+	+	+	+	+	+	+	+	+	2
1 TO 2 1/2		+	1	3	1	+	+	1	3	9
3 TO 6		+	+	2	3	1	2	2	12	23
7 TO 15	+		+	+	2	2	6	7	49	66
20 TO 30										
35 OR MORE										
TOTAL	+	1	1	6	6	4	8	10	65	100

D OVER			TOTAL OBS.
			+
			2
			21
			79
			200
+			383
+	+	+	615
+	1	1	819
+	1	1	814
1	+	3	755
1	1	1	697
+	1	1	692
1	1	1	701
+	1	1	784
1	1	2	846
+	+	1	637
	+	1	360
+	+	1	202
+	+		109
+	+		38
			11
			2
6	8	15	8767

0).
y

B PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED:

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (IN MILES PER HOUR) 0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 & OVER	TOTAL	AV SPEED
N	+	1	2	1	+	+	+	+		4	10.2
NNE	+	2	3	2	+	+	+	+	+	8	10.4
NE	1	2	2	2	+	+	+	+		6	9.6
ENE	+	1	1	1	+	+	+			4	9.7
E	1	1	1	+	+	+	+	+		4	7.6
ESE	+	1	2	1	+	+	+	+		4	8.9
SE	+	1	1	1	+	+				2	8.8
SSE	+	1	2	1	+	+	+			4	9.1
S	1	1	1	1	+	+	+			4	8.0
SSW	1	3	3	2	+	+	+	+		9	8.9
SW	2	4	3	1	+	+	+			10	7.5
WSW	1	3	3	2	+	+	+			8	9.1
W	1	2	2	2	+	+	+	+		7	10.1
WNW	+	1	3	3	1	+	+	+		9	12.4
NW	+	1	2	3	1	+	+	+		8	13.0
NNW	+	1	2	3	1	+	+			7	12.8
CALM	1									1	
TOTAL	11	25	34	24	5	1	+	+	+	100	9.8

D	NO OF DAYS WITH
29	60
8	12
15	33
5	27
1	21
+	20
	9
	1
.59	182

E PERCENTAGE FREQUENCIES OF SKY COVER, WIND, AND RELATIVE HUMIDITY:

HOUR OF DAY	CLOUDS SCALE 0-10: 0-3	4-7	8-10	WIND SPEED (M P H): 0-3	4-12	13-24	25-& OVER	RELATIVE HUMIDITY (%): 0-29	30-49	50-69	70-79	80-89	90-100
00	48	8	44	16	65	18	1	+	8	35	21	19	17
01	48	8	44	17	65	18	+	+	6	34	21	21	19
02	48	8	43	20	62	18	+	+	5	32	20	22	21
03	48	8	44	20	62	18	+	+	4	30	19	24	22
04	46	10	44	20	63	17	+	+	3	28	19	24	25
05	42	11	46	19	63	17	1		3	27	19	25	26
06	38	11	50	18	63	18	1		3	30	19	24	24
07	36	13	52	14	63	23	1	+	5	36	19	20	20
08	36	13	51	10	60	28	1	+	11	41	17	16	14
09	37	14	49	7	58	33	1	1	20	43	14	12	12
10	35	15	50	7	56	36	2	1	29	40	11	8	10
11	33	17	50	6	53	39	2	2	38	35	9	7	9
12	31	18	51	5	51	42	2	4	43	31	8	6	8
13	31	17	52	4	48	45	2	6	45	28	8	6	8
14	30	19	51	3	48	47	2	7	46	27	7	6	8
15	31	19	50	3	50	45	3	7	44	27	8	7	7
16	33	18	50	3	52	43	2	7	41	29	9	7	8
17	36	17	47	4	57	38	1	5	36	33	10	8	8
18	39	15	46	6	62	31	1	3	29	37	12	10	9
19	41	14	45	8	65	26	1	2	23	39	14	12	11
20	43	13	44	10	64	25	1	1	18	40	16	13	12
21	45	11	44	11	64	24	1	1	14	39	18	15	13
22	46	10	43	12	65	23	1	+	12	39	19	17	14
23	47	9	44	14	64	21	1	+	9	38	19	18	16
AVG	40	13	47	11	59	29	1	2	21	34	15	14	14

NEWARK, N
Newark Ai

Mobile, Alabama

STATION NO — OCCURRENCES OF PRECIPITATION AMOUNTS: — NO. YEARS

01-5478 ANN — FREQUENCY OF OCCURRENCES FOR EACH HOUR OF THE DAY — 5

INTENSITIES	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DAYS
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	WITH
.01 IN.	3	5	4	4	4	2	2	2	4	4	5	3	3	4	6	5	6	5	5	5	5	4	4	4	6
.02 TO .09 IN.	8	6	7	7	8	7	7	7	8	9	8	8	10	14	13	13	11	11	13	10	9	7	8	7	34
.10 TO .24 IN.	3	4	2	3	2	3	4	4	4	7	3	4	4	5	4	6	4	4	5	4	3	3	2	3	22
.25 TO .49 IN.	1	1	1	1	1	1	1	2	2	*	1	2	3	3	4	2	2	3	2	2	1	1	1	1	18
.50 TO .99 IN.	1	*	*	*	1	1	1	*	*	*	1	1	2	2	2	1	2	1	2	1	1	*	1	*	20
1.00 TO 1.99 IN.	*		*		*	*	*	*	*		*		*	1	*	*	1	*	1		*		*	*	15
2.00 IN. AND OVER	*		*					*				*	*			*									5
TOTAL	17	16	15	15	16	14	16	16	18	20	18	19	23	29	29	27	26	24	26	21	20	15	16	15	121

Seattle, Washington

STATION NO. OCCURRENCES OF PRECIPITATION AMOUNTS: NO. YEARS

45-7433 ANN FREQUENCY OF OCCURRENCES FOR EACH HOUR OF THE DAY 5

INTENSITIES	A.M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	P.M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	DAYS WITH
.01 IN.	19	25	28	31	20	15	11	9	7	10	9	9	14	14	18	15	21	23	24	15	12	14	13	19	10
.02 TO .09 IN.	19	21	27	28	27	21	21	27	25	17	19	22	20	21	20	24	24	26	23	22	20	18	20	35	55
.10 TO .24 IN.	2	3	2	2	3	4	4	4	2	3	2	3	3	3	3	2	3	3	4	3	2	4	3	5	43
.25 TO .49 IN.	*		*		*					*		*			*			*		*		*	*		26
.50 TO .99 IN.		*																							18
1.00 TO 1.99 IN.											*														4
2.00 IN. AND OVER																									*
TOTAL	41	49	58	62	50	39	36	40	34	30	31	34	36	38	41	41	48	52	52	41	24	36	36	59	156

APPENDIX B, EXHIBIT B

FREQUENCY OF ANNUAL WEATHER OCCURRENCES BY WORK SHIFT

Location Portland, ME

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.016	.074	.118	.171	.579	.039	.003	.0
Afternoon	.013	.069	.118	.192	.586	.022	.001	.0
Night	.008	.057	.108	.207	.611	.009	.0	.0

Shift	Effective Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.069	.165	.160	.156	.408	.039	.003	.0
Afternoon	.057	.161	.175	.168	.416	.022	.001	.0
Night	.044	.147	.181	.183	.436	.009	.0	.0

Shift	Wind Speed <13	13-24	25+
Day	.5813	.3975	.0213
Afternoon	.8438	.2212	.0125
Night	.8375	.2571	.01

Shift	Cloud Cover Sunny
Day	.4200
Afternoon	.1837

Shift	Precipitation None or Trace	.01	.02-.09	.1+
Day	.916	.022	.046	.016
Afternoon	.913	.027	.048	.012
Night	.898	.031	.053	.018

Fog

(Visibility <1/16 Mile)

Average .013

Shift	Relative Humidity 90	90-100
Day	.835	.165
Afternoon	.700	.300
Night	.510	.490

Correction of Effective Temperature for Painters Only <5	5-19	20-29	30-39
.069	.141	.050	.013
.057	.138	.081	.018
.044	.123	.086	.022

Location Boston

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.002	0.036	0.089	0.168	0.641	0.055	0.009	0.0
Afternoon	0.001	0.030	0.080	0.174	0.664	0.046	0.005	0.0
Night	0.0	0.019	0.064	0.179	0.706	0.028	0.003	0.0

Shift	Effective Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.063	0.163	0.153	0.150	0.407	0.055	0.009	0.0
Afternoon	0.052	0.146	0.156	0.163	0.433	0.046	0.005	0.0
Night	0.037	0.131	0.165	0.173	0.463	0.028	0.003	0.0

Shift	Wind Speed <13	13-24	25+
Day	0.3925	0.5413	0.0688
Afternoon	0.4838	0.4750	0.0450
Night	0.5838	0.3800	0.0325

Shift	Cloud Cover Sunny
Day	0.4150
Afternoon	0.1812

Shift	Precipitation None or Trace	.01	.02-.09	.1+
Day	0.912	0.027	0.043	0.018
Afternoon	0.912	0.027	0.045	0.016
Night	0.903	0.031	0.046	0.020

Fog

(Visibility <1/16 Mile)

Average .01

Shift	Relative Humidity 90	90-100
Day	0.8900	0.1100
Afternoon	0.8500	0.1500
Night	0.7800	0.2200

Correction of Effective Temperature for Painters Only <5	5-19	20-29	30-39
0.063	0.101	0.040	0.003
0.052	0.091	0.041	0.003
0.037	0.076	0.041	0.005

Location New York

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.0	0.007	0.072	0.168	0.694	0.053	0.006	0.0
Afternoon	0.0	0.005	0.061	0.170	0.719	0.042	0.004	0.0
Night	0.0	0.003	0.047	0.169	0.750	0.029	0.002	0.0

Shift	Effective Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.028	0.121	0.154	0.161	0.476	0.053	0.006	0.0
Afternoon	0.023	0.108	0.162	0.165	0.497	0.042	0.003	0.0
Night	0.016	0.095	0.156	0.172	0.530	0.029	0.002	0.0

Shift	Wind Speed <13	13-24	25+
Day	0.4763	0.4800	0.0450
Afternoon	0.5713	0.4000	0.0313
Night	0.7050	0.2738	0.0200

Shift	Cloud Cover Sunny
Day	0.5612
Afternoon	0.1912

Shift	Precipitation None or Trace	.01	.02-.09	.1+
Day	0.926	0.020	0.039	0.015
Afternoon	0.925	0.021	0.040	0.014
Night	0.920	0.021	0.042	0.017

Fog

(Visibility <1/16 Mile)

Average 0.01

Shift	Relative Humidity 90	90-100
Day	0.8862	0.1138
Afternoon	0.8362	0.1638
Night	0.7325	0.2675

Correction of Effective Temperature for Painters Only <5	5-19	20-29	30-39
0.028	0.078	0.040	0.006
0.023	0.067	0.040	0.006
0.016	0.055	0.038	0.006

Location Philadelphia

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature							
	<5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.0	0.021	0.070	0.167	0.629	0.097	0.017	0.000
Afternoon	0.0	0.017	0.064	0.172	0.659	0.077	0.011	0.0
Night	0.0	0.013	0.048	0.171	0.719	0.046	0.004	0.0

Shift	Effective Temperature							
	<5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.019	0.105	0.144	0.150	0.473	0.093	0.016	0.000
Afternoon	0.016	0.096	0.150	0.158	0.493	0.077	0.011	0.0
Night	0.011	0.071	0.145	0.168	0.555	0.046	0.004	0.0

Shift	Wind Speed		
	<13	13-24	25+
Day	0.6188	0.3613	0.0175
Afternoon	0.7425	0.2475	0.0100
Night	0.8188	0.1788	0.0063

Shift	Cloud Cover
	Sunny
Day	0.4275
Afternoon	0.1925

Shift	Precipitation			
	None or Trace	.01	.02-.09	.1+
Day	0.935	0.018	0.036	0.011
Afternoon	0.929	0.020	0.037	0.014
Night	0.923	0.020	0.039	0.018

Fog

(Visibility <1/16 Mile)

Average 0.01

Shift	Relative Humidity	
	90	90-100
Day	0.9062	0.0938
Afternoon	0.8800	0.1200
Night	0.7137	0.2863

Correction of Effective Temperature for Painters Only			
<5	5-19	20-29	30-39
0.019	0.079	0.052	0.012
0.016	0.073	0.055	0.015
0.011	0.050	0.053	0.019

Location Baltimore

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.0	.017	.065	.163	.622	.107	.025	.0
Afternoon	.0	.016	.061	.160	.660	.087	.017	.0
Night	.0	.015	.055	.166	.714	.048	.004	.0

Shift	Effective Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.023	.110	.157	.163	.415	.107	.025	0
Afternoon	.016	.093	.151	.162	.475	.087	.017	0
Night	.012	.078	.144	.167	.547	.048	.004	0

Shift	Wind Speed <13	13-24	25+
Day	.5900	.3813	.0300
Afternoon	.7136	.2688	.0138
Night	.8025	.1888	.01

Shift	Cloud Cover Sunny
Day	.4688
Afternoon	.2062

Shift	Precipitation None or Trace	.01	.02-.09	.1+
Day	.933	.020	.035	.012
Afternoon	.927	.020	.037	.016
Night	.929	.019	.038	.014

Fog
(Visibility <1/16 Mile)

Average .01

Shift	Relative Humidity 90	90-100
Day	.8912	.1088
Afternoon	.8575	.1425
Night	.6837	.3163

Correction of Effective Temperature for Painters Only <5	5-19	20-29	30-39
.023	.074	.051	.009
.016	.068	.056	.011
.012	.061	.058	.015

Location Norfolk, VA.

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.0	.003	.033	.111	.704	.121	.028	.0
Afternoon	.0	.001	.026	.106	.752	.097	.018	.0
Night	.0	0	.019	.100	.811	.063	.008	.0

Shift	Effective Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.007	.060	.112	.158	.514	.121	.028	.0
Afternoon	.004	.049	.104	.155	.573	.097	.018	.0
Night	.002	.036	.092	.155	.645	.063	.008	.0

Shift	Wind Speed <13	13-24	25+
Day	.5550	.4263	.0175
Afternoon	.7250	.2625	.0125
Night	.7313	.2588	.0100

Shift	Cloud Cover Sunny
Day	.4700
Afternoon	.1987

Shift	Precipitation None or Trace	.01	.02-.09	.1+
Day	.935	.017	.033	.015
Afternoon	.927	.020	.035	.018
Night	.932	.018	.037	.013

Fog
(Visibility <1/16 Mile)

Average .04

Shift	Relative Humidity 90	90-100
Day	.9375	.0825
Afternoon	.8375	.1625
Night	.6612	.3388

Correction of Effective Temperature for Painters Only <5	5-19	20-29	30-39
.007	.039	.028	.007
.004	.030	.027	.008
.002	.019	.024	.011

Location Mobile

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.0	0.000	0.008	0.043	0.689	0.210	0.049	0.000
Afternoon	0.0	0.0	0.006	0.037	0.789	0.145	0.023	0.0
Night	0.0	0.0	0.004	0.028	0.874	0.086	0.008	0.0

Shift	Effective Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.001	0.022	0.059	0.117	0.541	0.210	0.049	0.000
Afternoon	0.0	0.015	0.048	0.101	0.667	0.145	0.023	0.0
Night	0.0	0.009	0.036	0.082	0.779	0.086	0.008	0.0

Shift	Wind Speed <13	13-24	25+
Day	0.5763	0.4088	0.0175
Afternoon	0.7775	0.2163	0.0050
Night	0.8275	0.1638	0.0063

Shift	Cloud Cover Sunny
Day	0.4862
Afternoon	0.2087

Shift	Precipitation None or Trace	.01	.02-.09	.1+
Day	0.941	0.011	0.026	0.022
Afternoon	0.938	0.013	0.028	0.021
Night	0.957	0.010	0.020	0.013

Fog
(Visibility <1/16 Mile)

Average 0.01

Shift	Relative Humidity 90	90-100
Day	0.9087	0.0913
Afternoon	0.7187	0.2813
Night	0.4650	0.5350

Correction of Effective Temperature for Painters Only <5	5-19	20-29	30-39
0.001	0.012	0.011	0.001
0.0	0.007	0.010	0.001
0.0	0.004	0.006	0.001

Location New Orleans

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.0	.0	.001	.023	.682	.245	.048	.0
Afternoon	.0	.0	.0	.020	.758	.197	.026	.0
Night	.0	.0	.0	.015	.870	.106	.008	.0

Shift	Effective Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.0	.012	.043	.090	.560	.246	.048	.0
Afternoon	.0	.009	.031	.077	.662	.197	.026	.0
Night	.0	.005	.019	.058	.804	.106	.U08	.0

Shift	Wind Speed <13	13-24	25+
Day	.6025	.3825	.015
Afternoon	.8038	.1888	.0001
Night	.8425	.1475	.0001

Shift	Cloud Cover Sunny
Day	.6150
Afternoon	.2075

Shift	Precipitation None or Trace	.01	.02-.09	.1+
Day	.938	.012	.028	.022
Afternoon	.946	.013	.025	.016
Night	.960	.010	.017	.013

Fog
(Visibility <1/16 Mile)

Average .01

Shift	Relative Humidity 90	90-100
Day	.9125	.0875
Afternoon	.8087	.1913
Night	.4800	.5200

Correction of Effective Temperature for Painters Only <5	5-19	20-29	30-39
.0	.002	.002	.001
.0	.001	.002	.002
.0	.001	.001	.003

Location Houston

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.0	0.0	0.002	0.024	0.652	0.248	0.073	0.0
Afternoon	0.0	0.0	0.001	0.024	0.728	0.202	0.045	0.0
Night	0.0	0.0	0.002	0.022	0.855	0.108	0.013	0.0

Shift	Effective Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.001	0.014	0.048	0.106	0.510	0.248	0.073	0.0
Afternoon	0.0	0.012	0.044	0.094	0.602	0.203	0.045	0.0
Night	0.0	0.011	0.033	0.081	0.754	0.108	0.013	0.0

Shift	Wind Speed <13	13-24	25+
Day	0.4713	0.4838	0.0463
Afternoon	0.5600	0.4188	0.0188
Night	0.7463	0.2425	0.0100

Shift	Cloud Cover Sunny
Day	0.4400
Afternoon	0.2000

Shift	Precipitation None or Trace	.01	.02-.09	.1+
Day	0.953	0.013	0.026	0.018
Afternoon	0.955	0.013	0.020	0.012
Night	0.960	0.012	0.017	0.011

Fog

(Visibility <1/16 Mile)

Average 0.01

Shift	Relative Humidity 90	90-100
Day	0.9000	0.1000
Afternoon	0.8000	0.2000
Night	0.4637	0.5363

Shift	Correction of Effective Temperature for Painters Only <5	5-19	20-29	30-39
Day	0.001	0.005	0.004	0.0
Afternoon	0.0	0.004	0.004	0.0
Night	0.0	0.004	0.003	0.0

Location Galveston

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature							
	<5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.0	0.0	0.0	0.013	0.653	0.324	0.010	0.0
Afternoon	0.0	0.0	0.0	0.012	0.681	0.301	0.007	0.0
Night	0.0	0.0	0.0	0.009	0.717	0.270	0.004	0.0

Shift	Effective Temperature							
	<5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.001	0.015	0.041	0.089	0.519	0.324	0.010	0.0
Afternoon	0.0	0.015	0.036	0.080	0.561	0.301	0.007	0.0
Night	0.0	0.012	0.028	0.066	0.619	0.270	0.003	0.0

Shift	Wind Speed		
	<13	13-24	25+
Day	0.4550	0.5163	0.0300
Afternoon	0.5763	0.3975	0.0263
Night	0.6275	0.3438	0.0300

Shift	Cloud Cover
	Sunny
Day	0.4987
Afternoon	0.2112

Shift	Precipitation			
	None or Trace	.01	.02-.09	.1+
Day	0.955	0.011	0.021	0.013
Afternoon	0.968	0.010	0.014	0.008
Night	0.963	0.010	0.016	0.011

Fog
(Visibility <1/16 Mile)

Average .005

Shift	Relative Humidity	
	90	90-100
Day	0.8850	0.1150
Afternoon	0.7987	0.2013
Night	0.69	0.31

Correction of Effective Temperature for Painters Only			
<5	5-19	20-29	30-39
0.001	0.002	0.001	0.0
0.0	0.002	0.001	0.0
0.0	0.001	0.0	0.0

Location San Diego, CA

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.0	.0	.0	.001	.963	.033	.003	.0
Afternoon	.0	.0	.0	.0	.986	.013	.0	.0
Night	.0	.0	.0	.0	.991	.008	.0	.0

Shift	Effective Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.0	.0	.0	.018	.946	.033	.003	.0
Afternoon	.0	.0	.0	.016	.971	.013	.0	.0
Night	.0	.0	.001	.018	.973	.008	.0	.0

Shift	Wind Speed <13	13-24	25+
Day	.8638	.1350	.0025
Afternoon	.9638	.0350	.0013
Night	.9800	.0200	.0013

Shift	Cloud Cover Sunny
Day	.6265
Afternoon	.2750

Shift	Precipitation None or Trace	.01	.02-.09	.1+
Day	.983	.006	.007	.004
Afternoon	.981	.006	.010	.003
Night	.975	.009	.013	.003

Fog
(Visibility <1/16 Mile)
Average .01

Shift	Relative Humidity 90	90-100
Day	.9862	.0138
Afternoon	.9512	.0488
Night	.8275	.1725

Correction of Effective Temperature for Painters Only <5	5-19	20-29	30-39
.0	.0	.0	.0
.0	.0	.0	.0
.0	.0	.0	.0

Location Los Angeles

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature							
	<5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.0	0.0	0.0	0.001	0.966	0.030	0.002	0.000
Afternoon	0.0	0.0	0.0	0.000	0.988	0.011	0.0	0.0
Night	0.0	0.0	0.0	0.002	0.989	0.009	0.0	0.0

Shift	Effective Temperature							
	<5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.0	0.000	0.006	0.049	0.912	0.030	0.002	0.000
Afternoon	0.0	0.0	0.002	0.040	0.946	0.011	0.0	0.0
Night	0.0	0.0	0.004	0.041	0.946	0.009	0.0	0.0

Shift	Wind Speed		
	<13	13-24	25+
Day	0.7838	0.2100	0.0063
Afternoon	0.8675	0.1275	0.0038
Night	0.9738	0.0263	0.0013

Shift	Cloud Cover
	Sunny
Day	0.3950
Afternoon	0.2600

Shift	Precipitation			
	None or Trace	.01	.02-.09	.1+
Day	0.974	0.006	0.008	0.012
Afternoon	0.978	0.005	0.014	0.003
Night	0.977	0.007	0.011	0.005

Fog (Visibility <1/16 Mile)	
Average	0.01

Shift	Relative Humidity	
	90	90-100
Day	0.9737	0.0263
Afternoon	0.9112	0.0888
Night	0.7762	0.2238

Shift	Correction of Effective Temperature for Painters Only			
	<5	5-19	20-29	30-39
Day	0.0	0.0	0.0	0.0
Afternoon	0.0	0.0	0.0	0.0
Night	0.0	0.0	0.0	0.0

Location Portland, OR

FREQUENCY OF ANNUAL OCCURRENCES

	Drybulb Temperature							
Shift	<5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.0	.002	.019	.097	.84[illegible]	.033	.006	.0
Afternoon	.0	.001	.018	.111	.83[illegible]	.032	.004	.0
Night	.0	.0	.019	.176	.803	.002	.0	.0

	Effective Temperature							
Shift	<5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	.006	.034	.096	.184	.641	.033	.006	.0
Afternoon	.004	.034	.102	.200	.624	.032	.004	.0
Night	.001	.032	.135	.275	.554	.002	.0	.0

	Wind Speed		
Shift	<13	13-24	25+
Day	.7638	.2238	.0100
Afternoon	.7763	.2163	.0088
Night	.8600	.1325	.0075

	Cloud Cover
Shift	Sunny
Day	.2987
Afternoon	.1500

	Precipitation			
Shift	None or Trace	.01	.02-.09	.1+
Day	.880	.043	.067	.010
Afternoon	.884	.043	.063	.010
Night	.885	.041	.065	.009

Fog
(Visibility <1/16 Mile)

Average .01

	Relative Humidity	
Shift	90	90-100
Day	.8712	.1288
Afternoon	.8275	.1725
Night	.6250	.3750

Correction of Effective Temperature for Painters Only			
<5	5-19	20-29	30-39
.006	.018	.016	.012
.004	.034	.019	.015
.001	.014	.029	.028

Location Seattle

FREQUENCY OF ANNUAL OCCURRENCES

Shift	Drybulb Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.0	0.003	0.018	0.123	0.838	0.016	0.002	0.0
Afternoon	0.0	0.002	0.017	0.138	0.830	0.013	0.001	0.0
Night	0.0	0.001	0.015	0.199	0.783	0.002	0	0.0

Shift	Effective Temperature <5	5-19	20-29	30-39	40-79	80-89	90-99	100+
Day	0.005	0.056	0.158	0.247	0.517	0.016	0.002	0.0
Afternoon	0.002	0.056	0.169	0.263	0.496	0.013	0.001	0.0
Night	0.001	0.064	0.211	0.320	0.402	0.002	0	0.0

Shift	Wind Speed <13	13-24	25+
Day	0.6000	0.3638	0.0338
Afternoon	0.6088	0.3688	0.0225
Night	0.7200	0.2638	0.0188

Shift	Cloud Cover Sunny
Day	0.2962
Afternoon	0.1475

Shift	Precipitation None or Trace	.01	.02-.09	.1+
Day	0.902	0.031	0.059	0.008
Afternoon	0.883	0.047	0.061	0.009
Night	0.864	0.058	0.068	0.010

Fog (Visibility <1/16 Mile)

Average 0.02

Shift	Relative Humidity 90	90-100
Day	0.8050	0.1950
Afternoon	0.7600	0.2400
Night	0.4925	0.5075

Correction of Effective Temperature for Painters Only <5	5-19	20-29	30-39
0.005	0.022	0.025	0.009
0.002	0.027	0.027	0.011
0.001	0.018	0.040	0.020

APPENDIX C

WEATHER EFFECTS ON OUTDOOR WORK EFFICIENCY

A review of the literature was undertaken to establish, to the extent possible, quantitative efficiency coefficients for outdoor workers engaged in “shipyard-like” activities, as influenced by climatic conditions. Unfortunately, the published literature in this area provides little useful information in a form that can be directly applied. Where data are available, generally they are in the form of physiological factors which are not directly related to either weather factors or laborer efficiency.

From the limited literature which is applicable (see Bibliography at end of the Appendix), the following summary of weather effects can be established.

The important climatic conditions affecting outdoor workers are:

- Temperature: high, low, diurnal and annual range
- Precipitation: rain, snow, sleet and ice
- Humidity: also presences of salt
- Wind: also presence of sand or dust
- Miscellaneous: sunlight, fog.

Temperature

Figure 1 summarizes data from eight sources. Variations reflect measurements of work activities requiring different skills. Furthermore, some efficiency loss data were campiled from studies where only the tempo of the actual work was measured. Time to warm the hands or feet in winter, or time to cool off in summer, was not included. These higher estimates of efficiency are, therefore, probably conservative, since total loss in work time was not

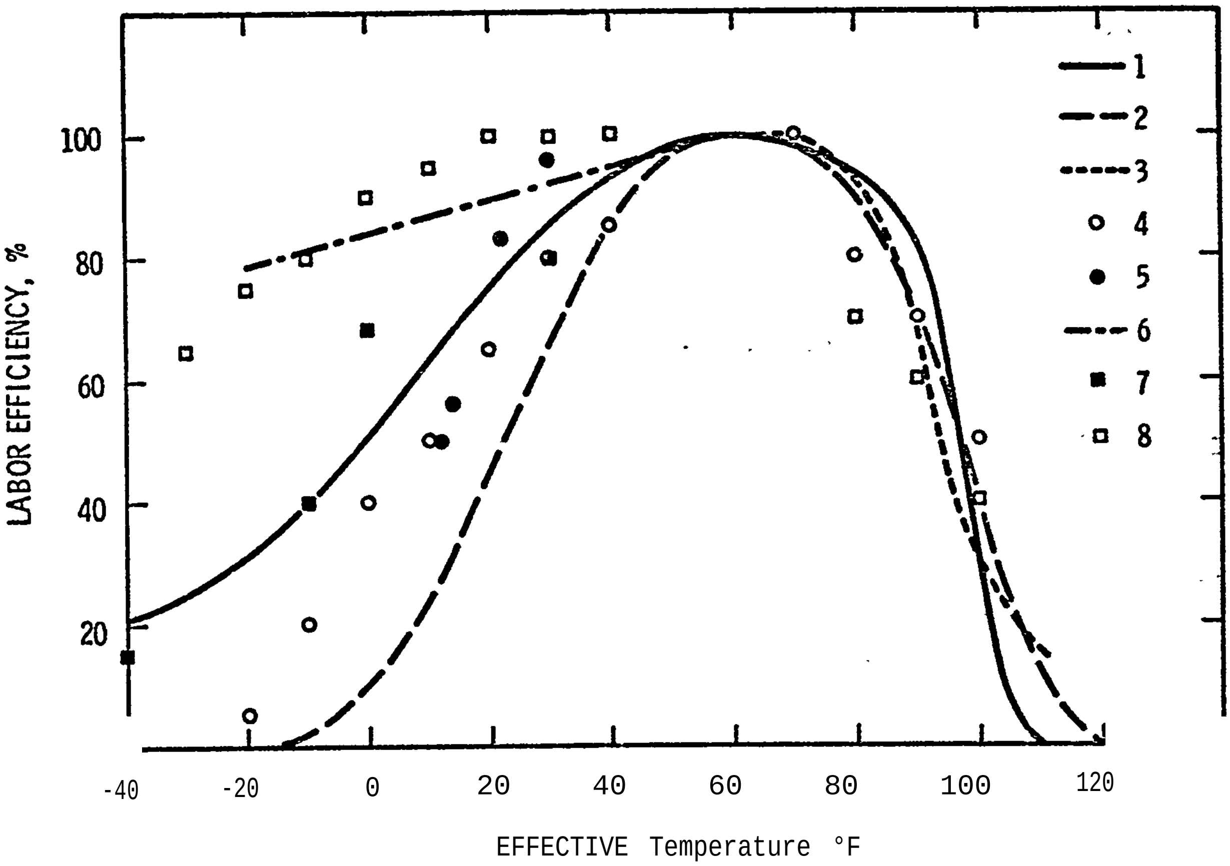

FIGURE C-1. Outdoor Worker Efficiency

LEGEND

1. Doyle, "Controlling Climate Effects", Tool Engr., 1955 (efficiency curve prepared under condition of little or no wind).
2. General Dynamics, Quincy (DX Study).
3. ASHVE Guide and Data Book (men at work 90,000 ft-lb of work per hour).
4. Constructor, May 1972 (welders, pipefitters, carpenters, electricians).
5. Unidentified shipyard estimate (converted from equivalent temperature to effective temperature).
6. Bechtel construction project in Canada (winter) - (Converted from wind chill temperature and corrected to 100% efficiency at 60"F).
7. ASHVE Guide and Data Book (Armstrong's data for line-maintenance job).
8. Constructor, May 1972 (laborers, ironworkers, operating engineers].

really considered. Another factor that would decrease efficiency even further is bad "ground" conditions resulting from ice, water or mud. When such conditions prevail, the estimates are quite conservative.

Wind

Human efficiency is significantly affected by cooling, which is a function of both temperature and of wind speed. Studies by the U.S. Army Quartermaster Corps resulted in the computation of a "wind chill factor" by which the effect of temperature and wind can be objectively evaluated (see Figures C-2 and C-3). Most outdoor operations cease when the chill factor reaches 1200, "bitter cold".

Wind also hinders the movement and positioning of large pieces and increases paint losses. Wind "noise" reduces effective communication between workers. Wind-blown dust and salt sprays increase maintenance problems with equipment.

Another method used to measure the effective of temperature and wind is effective temperature (ET). The ET is determined from dry- and wet-bulb temperatures and air motion by reference to standard ET charts. When a wind is blowing, the ET can be estimated by lowering the measured temperature one degree for each one mile per hour of wind, using a practice adopted by environmental engineers.

The curves in Figure 1 are plotted against ET although the difference between ET and wind chill temperature (equivalent temperature) is seldom great. The ET index is most applicable to warm atmospheres when radiation effects are not significant. An ET of 78 represents the threshold of sweating, while an ET of 90 is the upper limit for continuous exposure of heat-acclimatized men engaged in light activities. The upper permissible limit for moderately hard work is an ET of 85, and for heavy work, 80 ET. In hot spaces of Naval ships (underway), 91 ET is well tolerated during the usual 4-hr watches.[1]

At moderate temperatures, depending upon the work being done, labor efficiency gradually declines with increasing wind speeds over 15 mph and

TEMP →	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
WIND MPH ↓	WIND CHILL INDEX (EQUIVALENT TEMPERATURE) - EQUIVALENT IN COOLING POWER ON EXPOSED FLESH UNDER CALM CONDITIONS																
CALM	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	33	27	21	16	12	7	1	-6	-11	-15	-20	-26	-31	-35	-41	-47	-54
10	21	16	9	2	-2	-9	-15	-22	-27	-31	-38	-45	-52	-58	-64	-70	-77
15	16	11	1	-6	-11	-18	-25	-33	-40	-45	-51	-60	-65	-70	-78	-85	-90
20	12	3	-4	-9	-17	-24	-32	-40	-48	-52	-60	-68	-76	-81	-88	-96	-103
25	7	0	-7	-15	-22	-29	-37	-45	-52	-58	-67	-75	-83	-89	-96	-104	-112
30	5	-2	-11	-18	-26	-33	-41	-49	-56	-63	-70	-78	-87	-94	-101	-109	-117
35	3	-4	-13	-20	-27	-35	-43	-52	-60	-67	-72	-83	-90	-98	-105	-113	-123
40	1	-4	-15	-22	-29	-36	-45	-54	-62	-69	-76	-87	-94	-101	-107	-116	-128
45	1	-6	-17	-24	-31	-38	-46	-54	-63	-70	-78	-87	-94	-101	-108	-118	-128
50	0	-7	-17	-24	-31	-38	-47	-56	-63	-70	-79	-88	-96	-103	-110	-120	-128

VERY COLD

BITTERLY COLD

EXTREME COLD

EXPOSED FLESH FREEZES

WIND SPEEDS GREATER THAN 40 MPH HAVE LITTLE ADDITIONAL CHILLING EFFECT

Figure C-2 - The U.S. Army Wind Chill Index

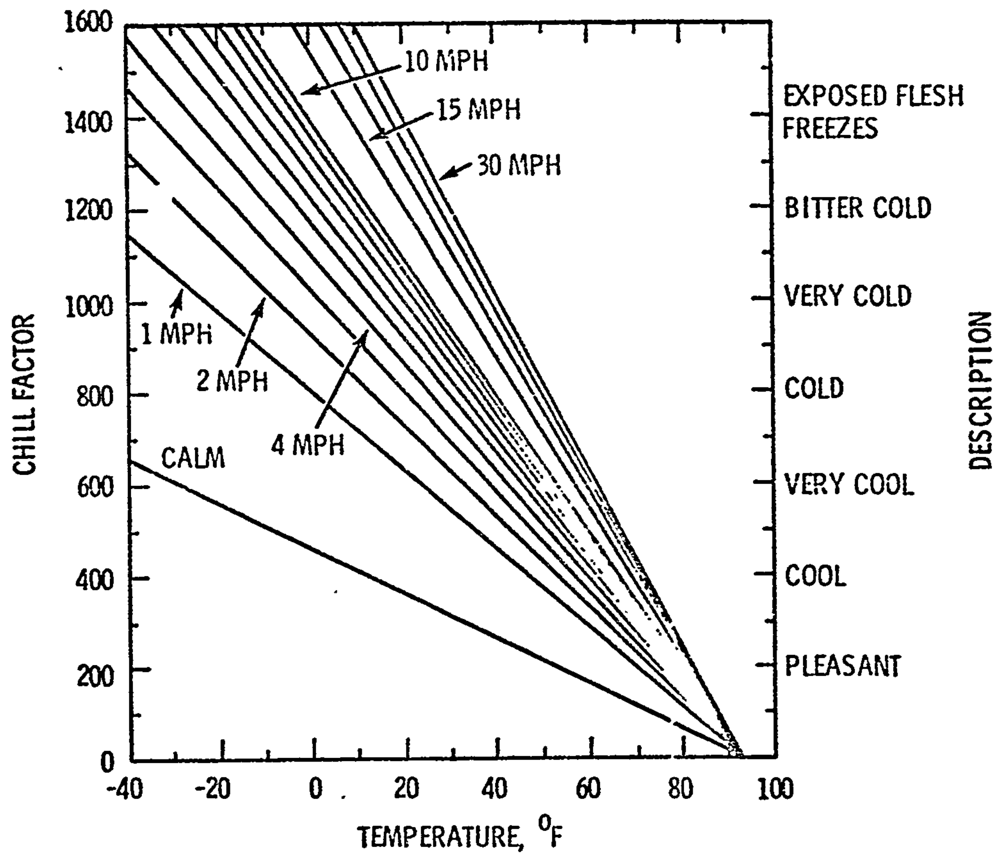

Figure C-3 - Chill Factor for Selected Wind Speeds

rapidly approaches zero between 40 and 60 mph. Winds of 40 mph are likely to stop work on exposed staging.(1)

Precipitation

Rain decreases efficiency. Under rainy conditions at 50°F and without wind, workers well clothed in rain trousers, jackets, hats and boots lose only about 10% in efficiency. When exposed to rain and strong winds, men cannot remain dry for much more than one hour regardless of how well they are clothed.

At low temperatures, labor efficiency and safety are still further impaired by precipitation. Sleet or ice are considered more limiting to outside work than rain or snow. Workers will generally not continue working during a sleet storm. Precipitation has been found more serious than freezing temperatures in reducing efficiency of an outside railroad car building line in a mild climate. In 23 days of rain, 97 cars or about 35% were lost out of a scheduled 278. During 5 days of ice, snow, sleet and rain, 28 cars or 50% were lost out of a scheduled 56. Only 4 cars out of 14 were reported lost because of cold weather alone.

Besides discomfort, precipitation decreases efficiency by decreasing visibility; making parts, tools, and equipment slippery and hard to handle; and making working conditions more hazardous.

Humidity

Several comfort indexes have been devised to express the effect of temperature and humidity. There is general agreement that the comfort zone for normally efficient work extends to about 80°F with 50% relative humidity and to the mid-70's with 75% relative humidity. Discussions with construction personnel indicate that operations are not significantly affected until the temperature rises above 80°F. It is estimated that a reasonable threshold of temperature-humidity would be 85°F and 50%. This corresponds to a U.S. Weather Bureau Temperature-Humidity Index value of 77, and Table 1 gives several combinations of temperature and relative humidity that are equivalent.(2)

TABLE 1. U.S. Weather Bureau Temperature-Humidity Index

Temperature	Relative Humidity	Index
86	79	77
85	50	77
90	24	77
95	8	77

Reduced efficiency appears to occur at the following limits of temperature and humidity: (8)

Maximum Temperature		Humidity
85-89°	and	≥50%
90-94°	and	≥30%
95-99°	and	≥20%
100°	and	Any

Night Lighting

Shipyard estimates for improper lighting (outdoor areas) range from 10 to 25% productivity loss. Survey results by others show increases in work output of 3 to 20% are possible for heavy work activities similar to shipbuilding. These increases were brought about by illumination changes. Atypical example: original-4.6 fc, new-12.7 fc.

Fog

The, effect of fog is to reduce visibility. In shipbuilding this affects primarily riggers and crane operators who must be able to see the boom, the load being lifted and hand signals. Reduction of visibility to less than the boom length or the distance to a signaler stops crane work.

The 100% humidity accompanying fog also affects painting operations. It usually prevents painting outdoors.

Sunlight

The effect of sunlight, e.g. hot summer sun, is to reduce worker efficiency not only by raising the effective temperature but by heating steel plates to uncomfortably high temperatures. Personnel working on sun-heated surfaces are often forced to retire to a shaded area, provide shade or find work in a cooler location.

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APPENDIX D

TYPICAL HEATHER PROTECTION STRUCTURES IN U.S. SHIPYARDS

In the course of the study, nine U.S. Shipyards were visited. Photographs of some of the weather protective devices and structures were obtained and are shown on the following pages.

In addition to those devices pictured, numerous shelters of a temporary nature--plywood, tarpaulin or plastic on wood or scaffold framework--are used for rain and wind protection. Several shipyards use portable weather protective devices to keep welding electrodes dry. Each welder has a heated container which holds 10 pounds of electrodes and can be carried from place to place and plugged in to an outlet nearby. Used containership containers have also been utilized for storage, shops and office space in a U.S. shipyard.

An all-weather painting facility at the General Dynamics yard in Quincy, Massachusetts, has been in operation since 1968. It is able to handle subassemblies up to 50 ft square and 30 ft high. The facility includes climate control for painting and drying, telescoping doors for access, and a heating-ventilating system rated at 75,000 cfm.

The Ingalls Shipyard at Pascagoula, Mississippi, has installed a weather-protected shotblasting facility. It is able to handle 56 ft by 56 ft sections up to-100 tons.

Other examples of weather protection are shown in the following photographs.

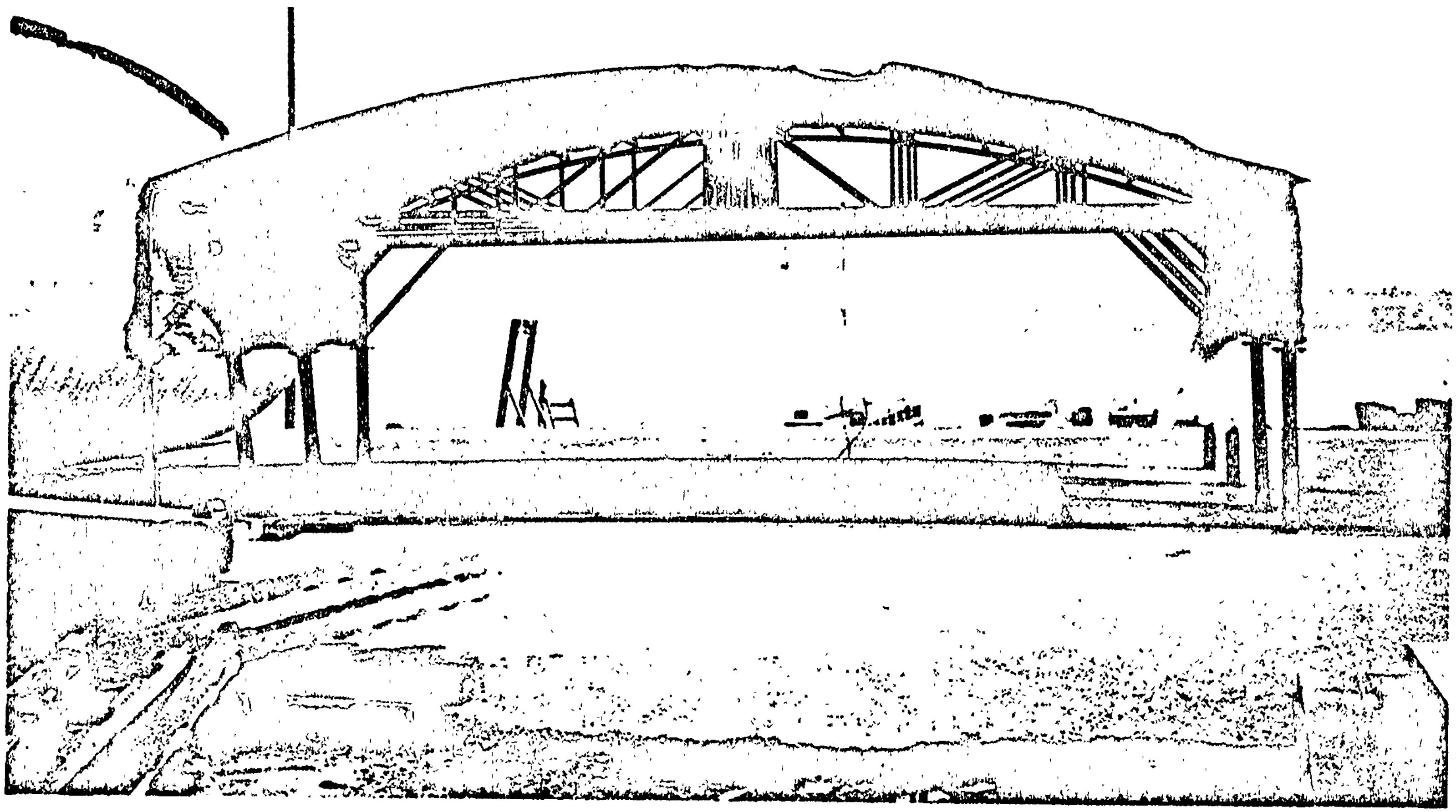


Figure D-1 - A portable steel shelter used to provide rain protection and shade for shipyard work either on the ground or on the deck of a ship or barge. Courtesy of FMC, Marine and Rail Equipment Division, Portland, Oregon.

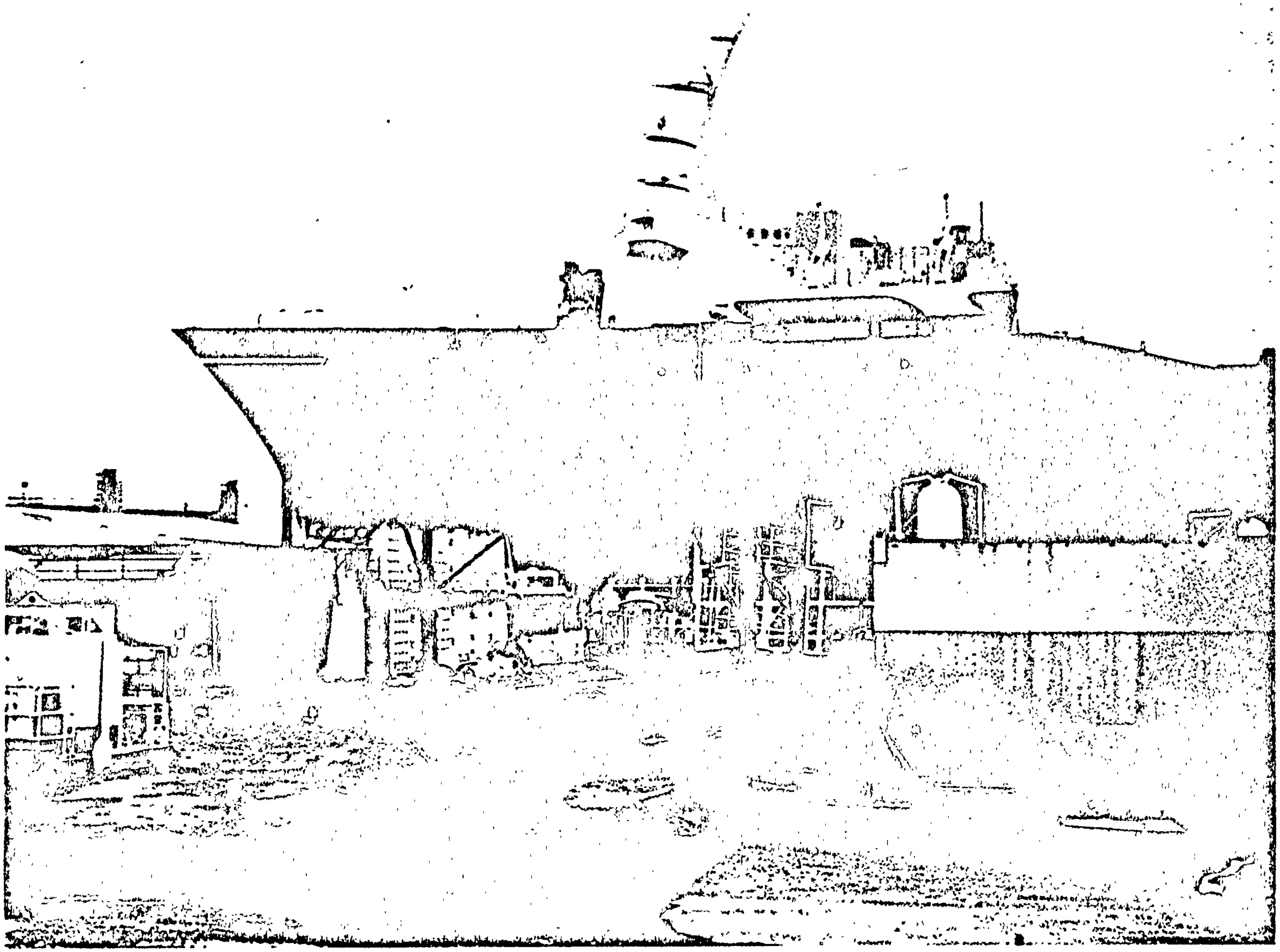


Figure D-2 - A portable steel shelter used to provide rain protection and shade for shipyard work either on the ground or on the deck of a ship or barge. Courtesy of Avondale Shipyards, Inc., New Orleans, Louisiana.

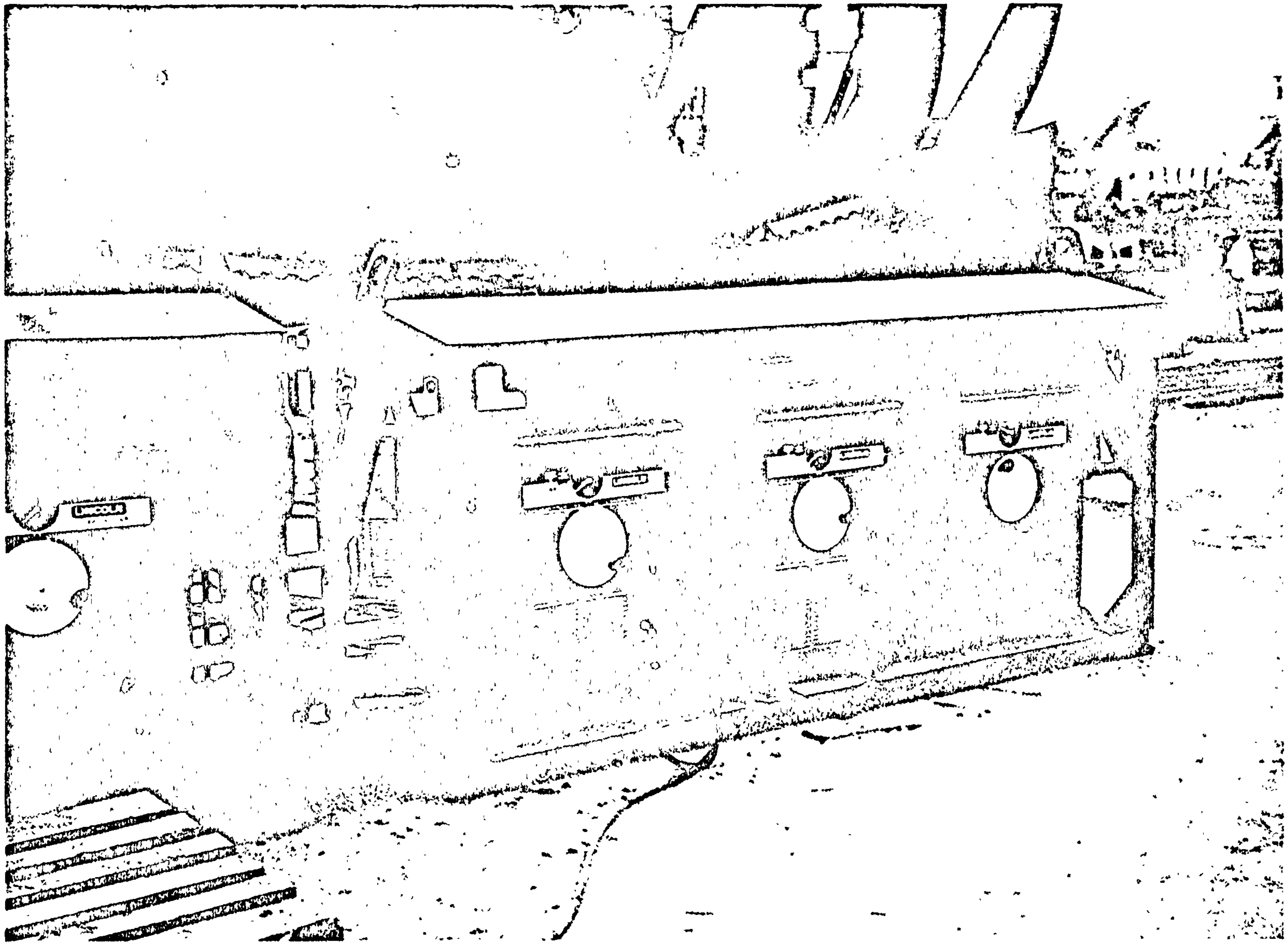


Figure D-3 - A close-up of a weather protective device for welding machines. The roof provides protection from the rain and hot sun both of which tend to shorten machine life. Fastening the machines to the frames gives an added bonus of rapid portability. Courtesy of Todd Shipyards Corporation, Houston, Texas.

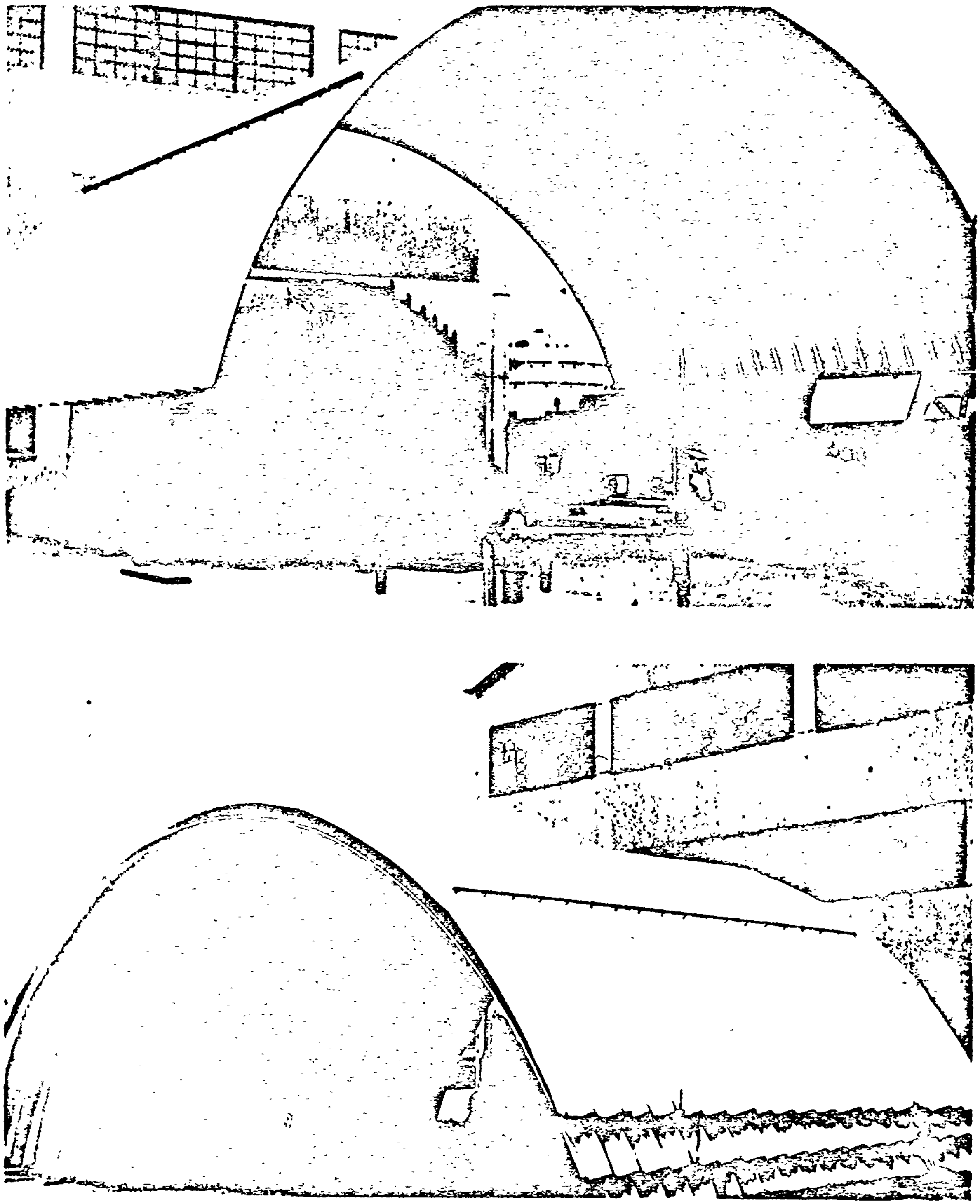


Figure D-4 - Heavy corrugated sheet metal roofs ("Wonderbuilding" arches) used for rain and shade protection for various operations. Units can be nested for storage as shown in lower photo.

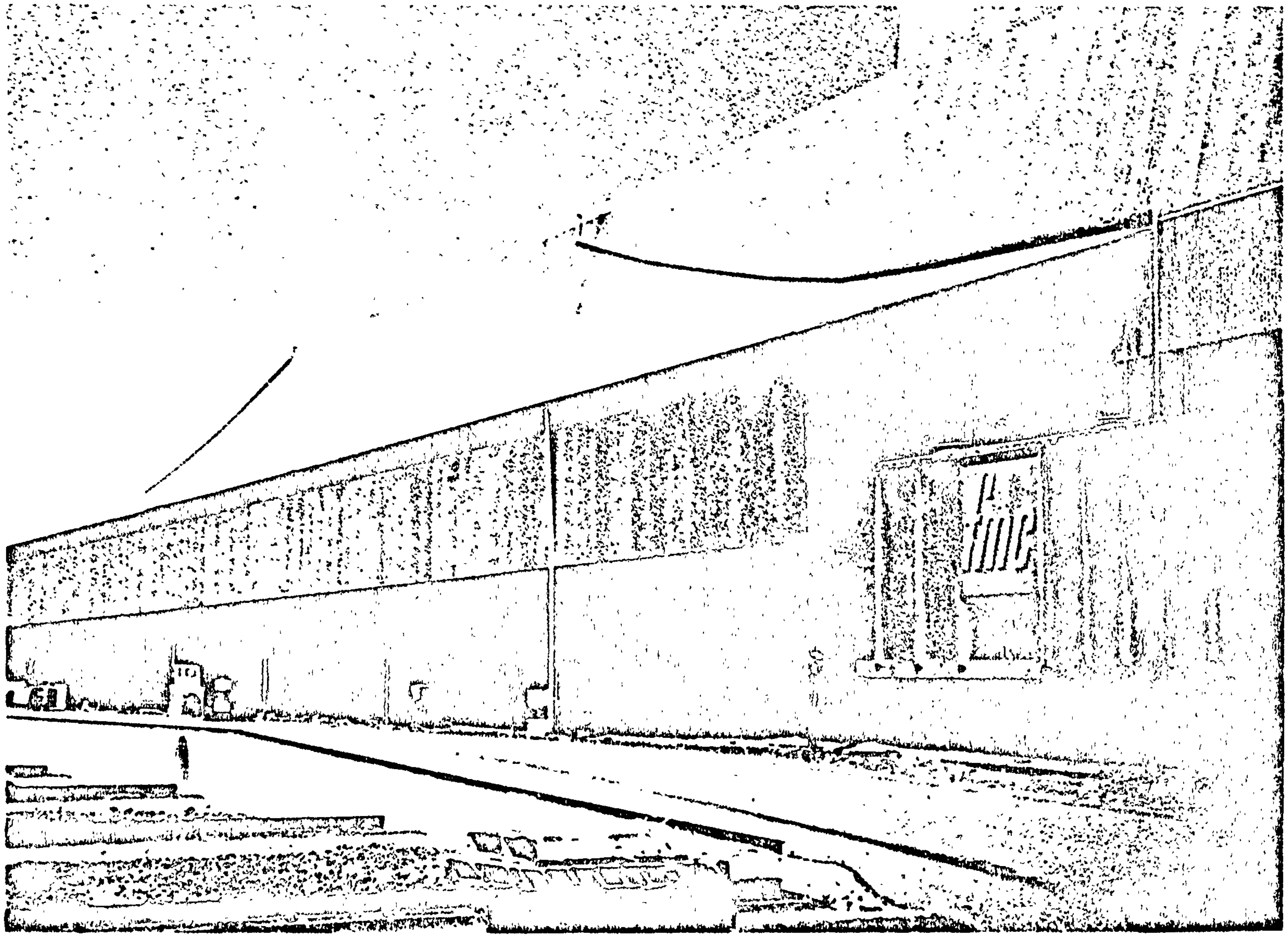


Figure D-5 - A lean-to addition used for rain and sun protection in heavy manufacturing (rail car). The shelter allows work to proceed in bad weather when it might otherwise be forced to shut down. Courtesy of FMC, Marine and Rail Equipment Division, Portland, Oregon.

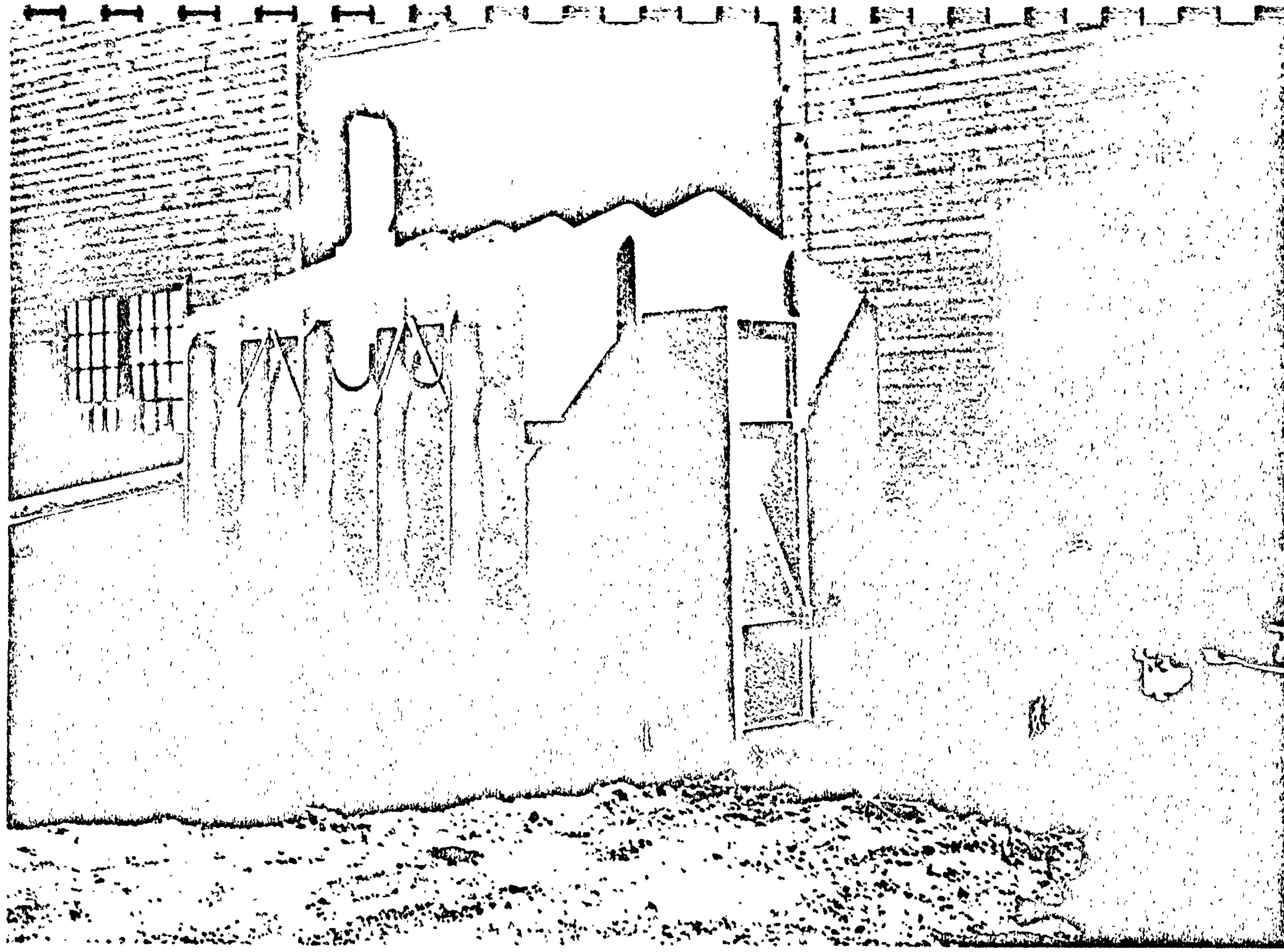


Figure D-6 - An all-weather protective shed for storage of paint and paint pumps. Electrically heated, it is a complete, portable paint station which prevents freezing of stored paint and the paint pumps and pots themselves. Courtesy of FMC, Marine and Rail Equipment Division, Portland, Oregon.

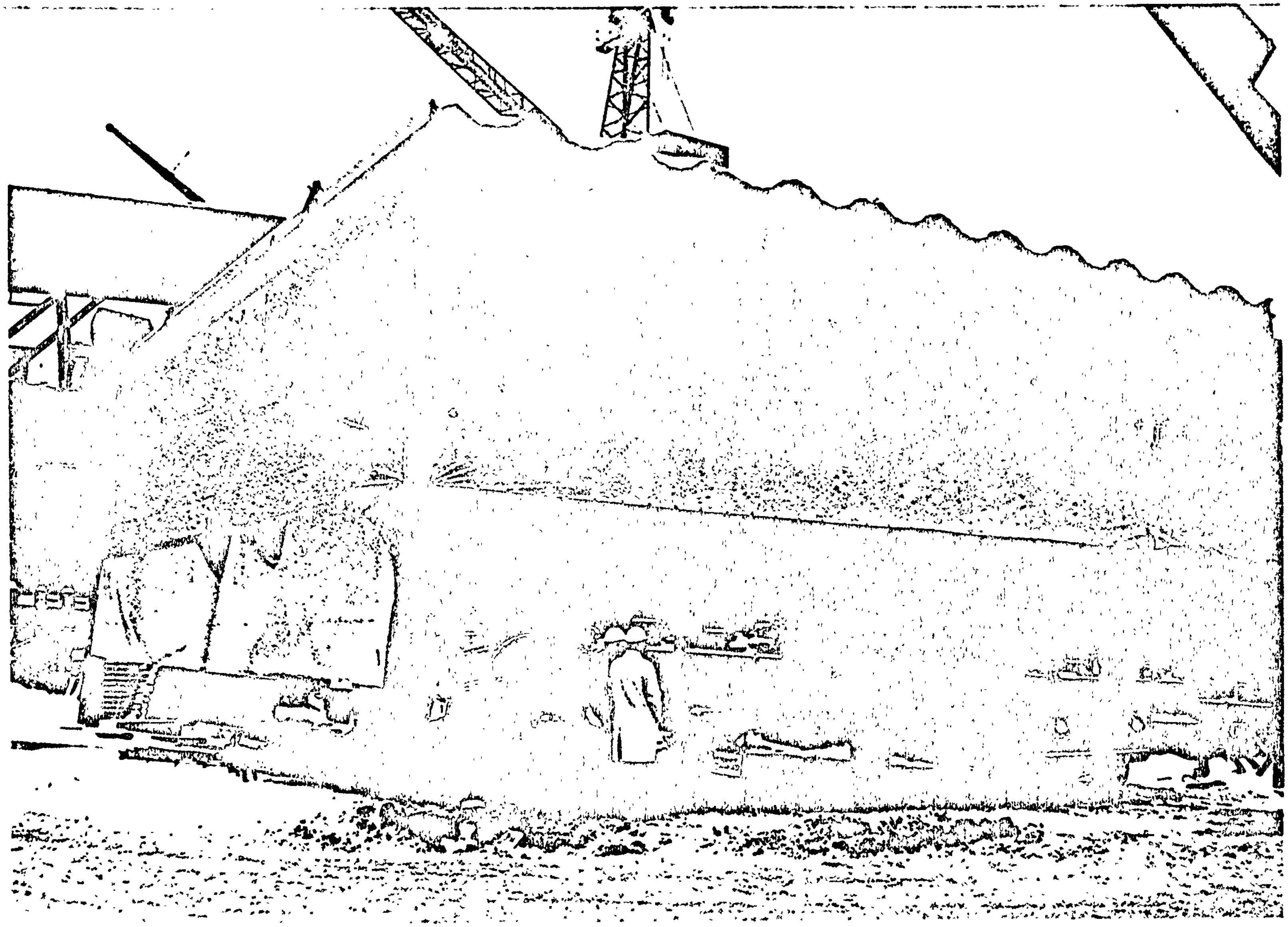
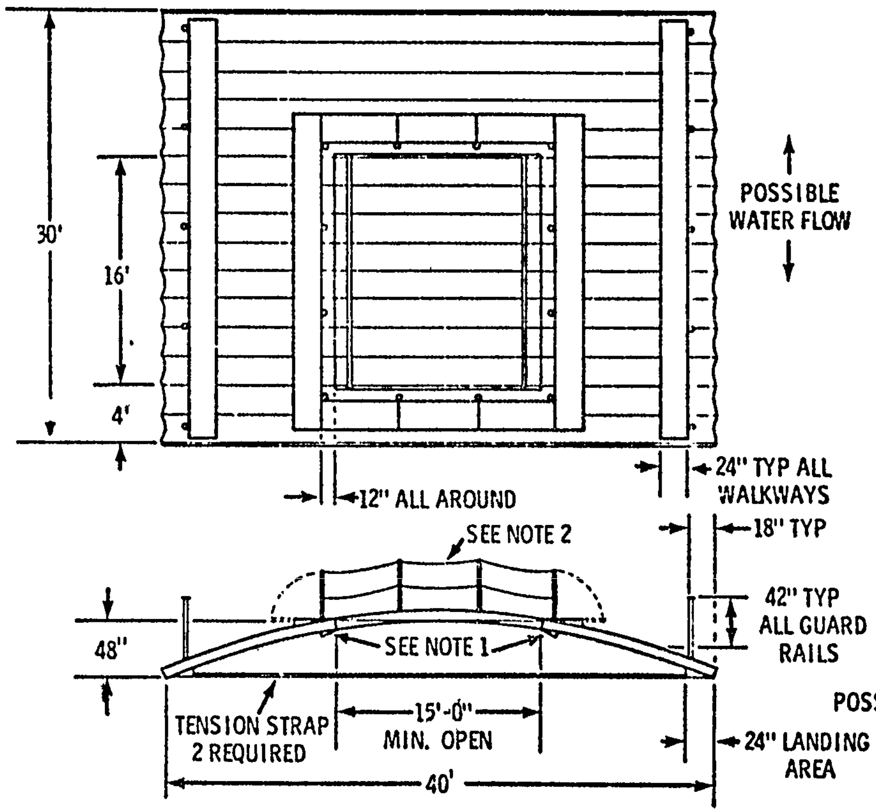


Figure D-7 - Temporary weather protective shelter. These portable structures measure 40 ft x 50 ft in plan with roof heights varying from 12-30 ft. The roof grid is assembled from cold rolled beams and supported on pipe columns. The roof cover is large corrugation metal sheeting. Removable rubberized canvas sidewalls provide additional protection. The shelter encloses sufficient volume to protect a variety of welding, blasting, painting and storage activities. Courtesy of Bath Iron Works Corporation, Bath, Maine.



NOTES:

1. RAIN REMOVAL SYSTEM TO HANDLE 4" OF WATER PER HOUR WHEN ROOF IS INSTALLED ON SLOPES UP TO 5/8" PER FOOT AND NOT ALLOW WATER TO PUDDLE CAUSING FREEZE DAMAGE.
2. SAFETY POLES AROUND HATCH OPENING TO FOLD DOWN OR OTHERWISE BE STOWED ON ROOF. CABLES MAY BE CONNECTED TOGETHER WITH SAFETY HOOKS OR EQUIV.
3. ROOF AND HATCH TO HAVE INDEPENDENT LIFTING PROVISIONS.
4. WALKWAYS TO BE EXPANDED METAL TYPE OR EQUIV. NON SKID MATERIAL.
5. ROOF TO BE STABLE ON SLOPES UP TO 5/8" PER FT.
6. ROOF TO HAVE ABILITY TO BE STACKED 4 HIGH AND WITHSTAND '2G' IMPACT LOADS.

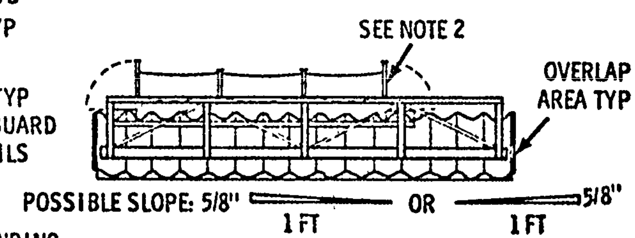


Figure D-8 - Design for a Portable, Trussless Cover with Hatch for Hull Construction - Newport News Shipbuilding and Dry Dock Company.

APPENDIX E

MODULAR WEATHER PROTECTION PANELS

HOARDING PANELS

Typical Design Criteria

1. Diffusion of Light

   Hoarding panels should be such that no auxiliary light is required during the normal daylight.

2. Resistance to Wind

   Closure system should be such that it could stand the high winds during the winter months (up to70 mph).

3. Strength of Panels

   Enclosures should be such that they could support the load of the different panel sections when installed one on top of the other. When used as the roof, they should also be able to support the snow load.

4. Loss of Heat

   The closure should be such that the heat loss is at a minimum.

5. Versatility

   Closures should be such that they could be adapted to numerous configurations, re: stand alone structures, structural steel requirements, etc.

Design Specifications

To meet the above criteria, one contractor assembled hoarding panels in an 8'-0" x 16'-0" size, which were constructed of 2 x 4 spruce frame with 2 x 4 studs at 2'-8" on center. Reinforced woven polyethylene was applied on the frame and was held in place by 1 x 2 lumber strips all over the frame and studs. Design of the hoarding panel is shown in Figure E-1.

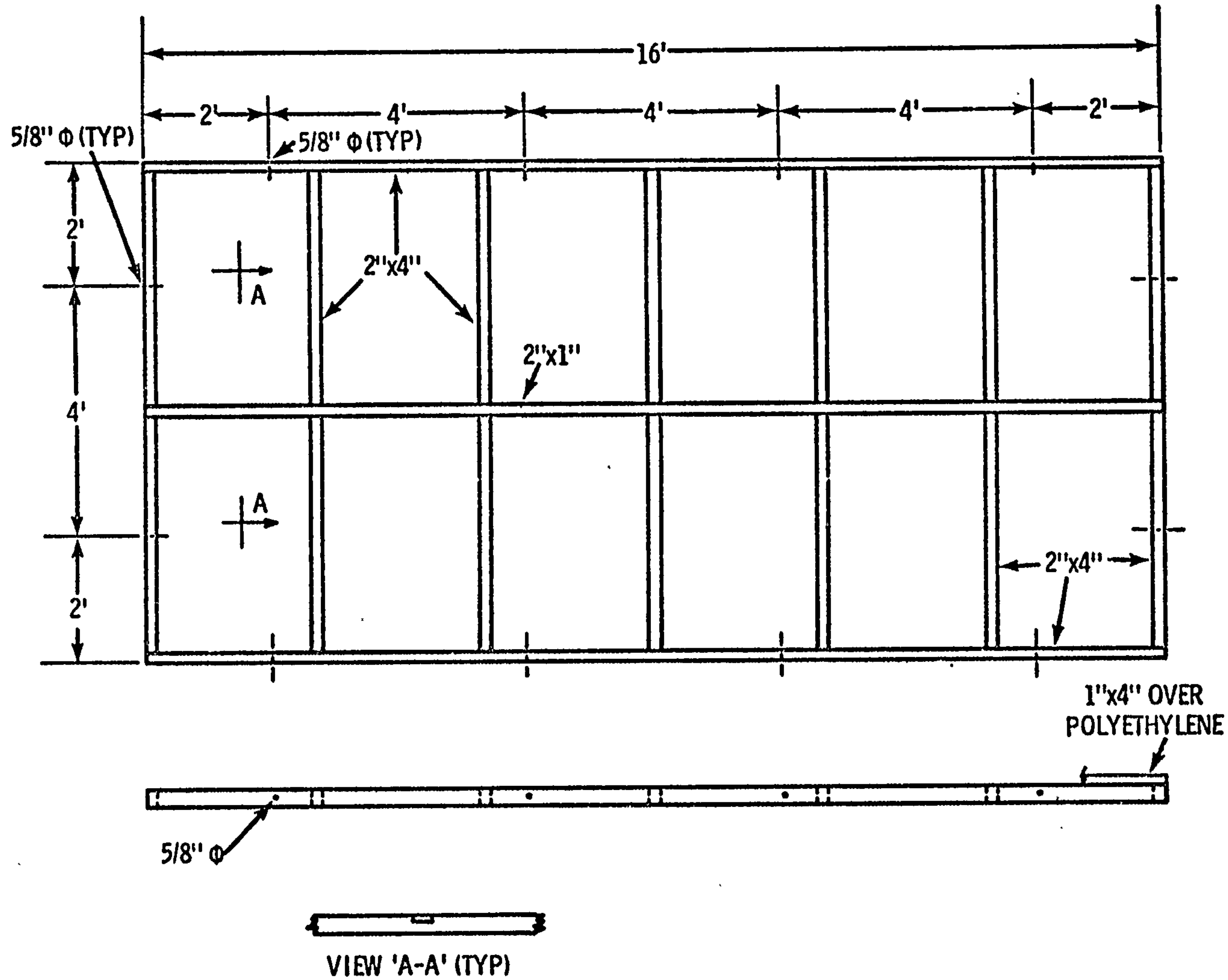


Figure E-1 - Design of Hoarding Panels

For the fabrication of the hoarding panels, a jig was made which permitted panels to be made in different sizes: 8' x 16', 6'x 16', 4' X 16', 2′ X 16′.

To minimize heat loss, two layers of polyethlene can be used, if necessary, with air gap up to a maximum of one inch between the two layers.

Erection

Hoarding panels are secured together by a tie and wedge system. Panels are then nailed to small wooden frames built around the steel building frame as shown in Figure E-2.

For the construction of structures inside a main building, hoarding panels are attached to one another to forma closure.

Cost of Hoarding Panels

A cost studies indicated that it is more economical to fabricate panels on the job site rather than purchase or rent them from others. Total cost of the hoarding panels is about $0.40/sq ft with a cost breakdown as follows:

Material	$0.09 Sq ft
Manufacture Labor	0.44 "
Erection Labor	0.19 "
Dismantle Labor	0.08 "
Total	$0.40 Sq ft

Average cost of one panel, 8x 16 ft= $48.00.

Figure E-3 illustrates portable welder’s shelter used in civil construction works.

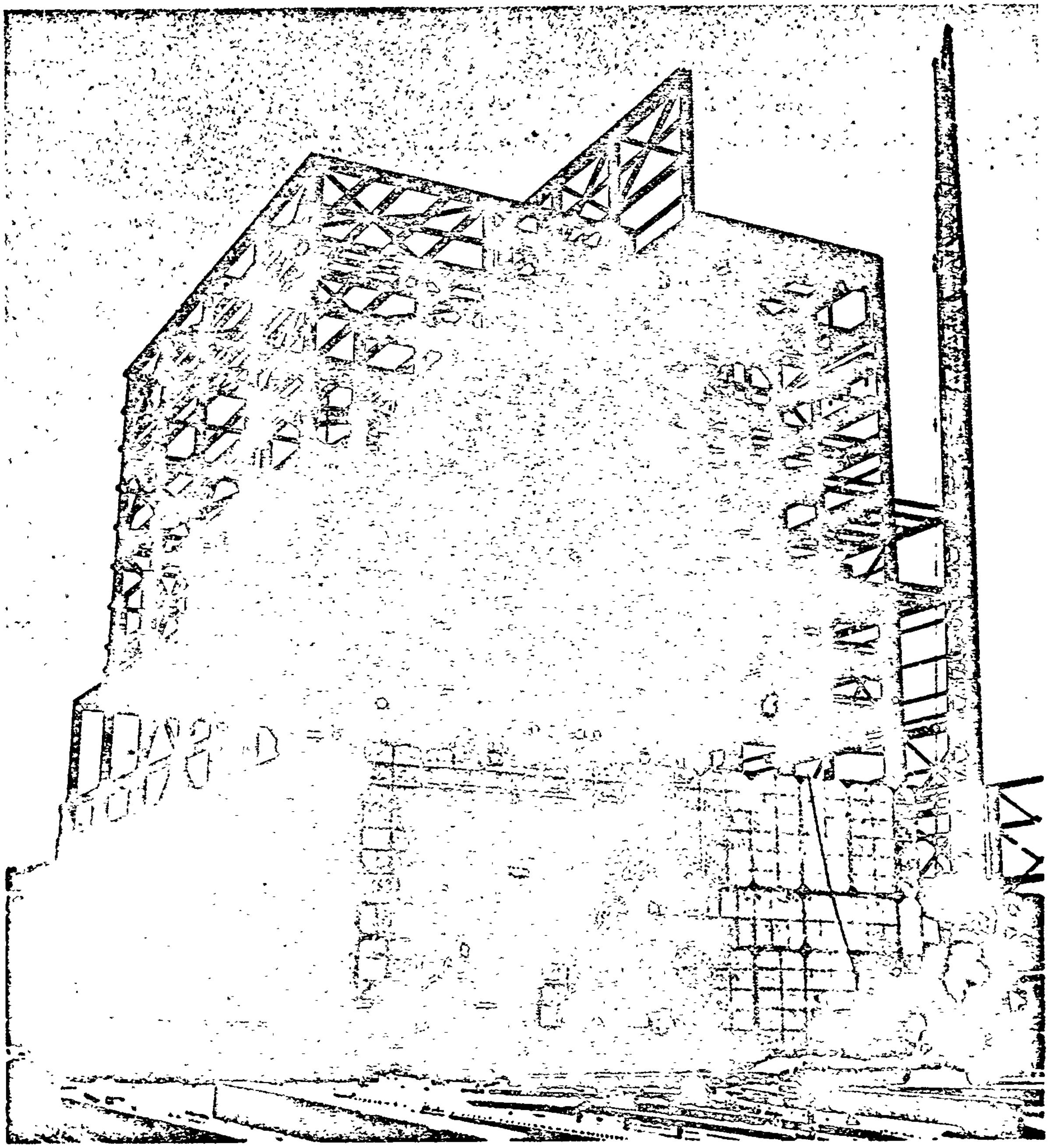


FIGURE E-2 - Hoarding Panels Attached to Building Frame to Form Weather Enclosure.

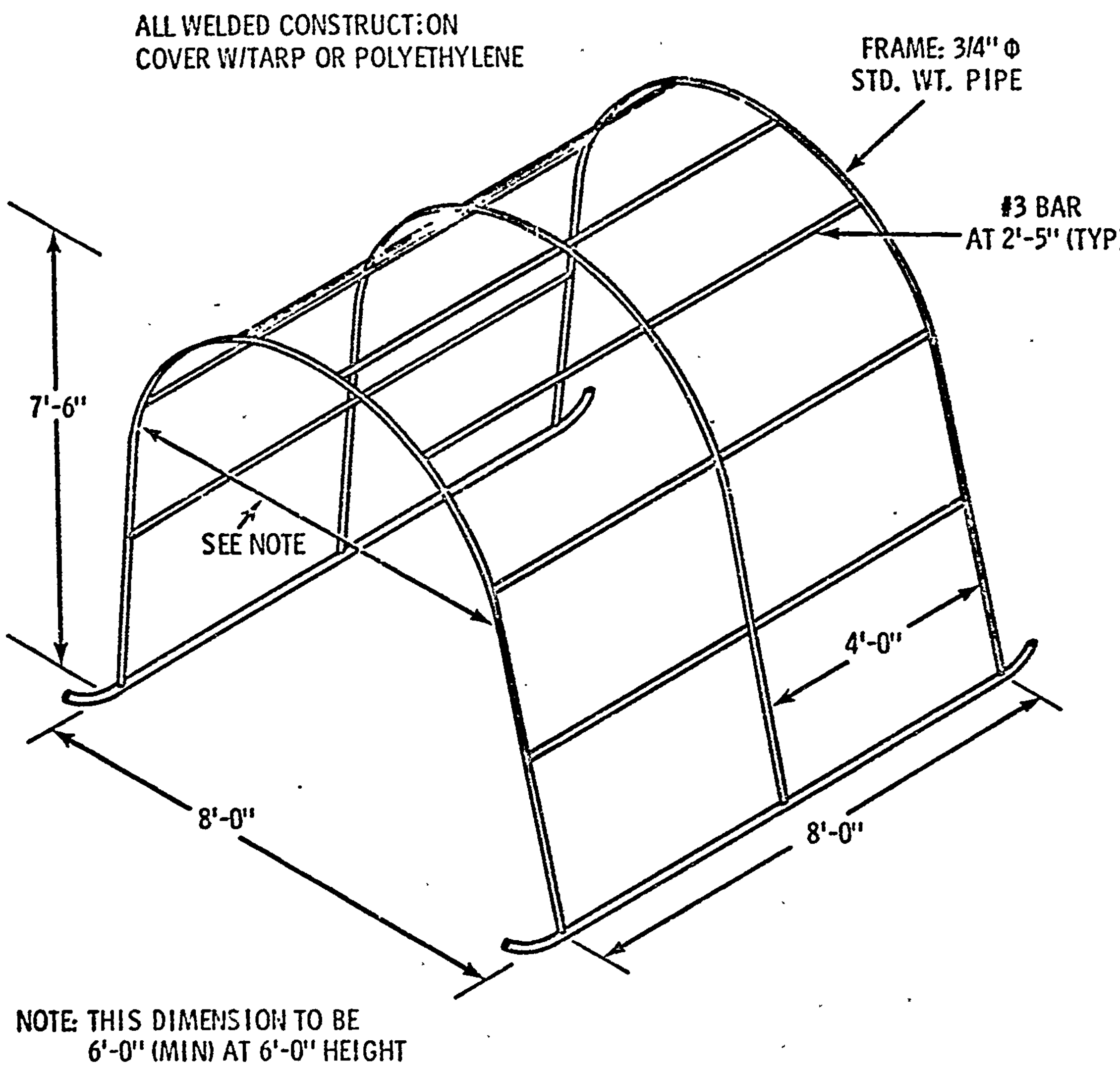


Figure E-3 - Portable Welder's Shelter

APPENDIX F

DESCRIPTION OF AIR-SUPPORTED SHELTER

A large, most unique shelter used on a civil works project in Canada was an "air shelter" or, as it is comnonly called, a "bubble". It is an air supported structure, a strong. flexible, balloon-like envelope, supported and stabilized by maintaining a small pressure differential within the envelope. The air supported shelter is a dynamic structure, as contrasted with a static pile of bricks, mortar of timbers, and is the ultimate in structural efficiency. There is no redundancy of structural material in the pretensioned shell and the apparent simplicity of the shelter belies the actual complexity of the design of all its components. The shell must tolerate and resist all the normal loadings experienced by any other type of structure. It does so with a shell measuring only a few hundredths of an inch thick.

Physical characteristics of the shell material, seam design, loading around the doorways, and the pressurization system must be carefully chosen and controlled to ensure satisfactory,life and usefulness.

The structure was 100′ wide, 200′ long, and 50′ high, with ends that were almost 'square". It covered an area of almost 20,000 sq.ft., the surface area of the shell Was 35,000 sq.ft. The fabric was guaranteed for eight years.

The bubble used a′ vinyl-coated nylon with a 2x 2 basket weave, having a tensile strength of 400 x 400 lb/in. The material was described as off-white which admitted sufficient light during the daytime for all types of work. Inside, the shell appeared to be an unusual orange-yellow color.

The joints were heat sealed to develop the full-strength of the fabric. The envelope was supplied in three sections which were joined by a single interlocking peg system which was readily assembled or disassembled without special tools. The sectionalizing permitted the individual packages to be kept to a reasonable size to handle and, also gave flexibility to the ultimate size of the shelter by adding or subtracting additional center sections when required.

Sandbags were installed in the ballast skirt, approximately six cubic feet of sand per foot of periphery, to hold the shell down and solid anchors were provided for the attachment of cables to isolate and redistribute the load around the doorways.

Two Buffalo-Forge, Model 600A, 3 H.P. centrifugal blowers, each having a free delivery of 14,000 cfm provided sufficient pressure for normal operation and the other was used for unusual conditions as well as beings standby unit. The inflation pressure was just less than one. inch of water, which resulted in a pressure of approximately 5 lb/sq.ft.

Automatic pressure controls operated the second blower when the internal pressure dropped because of excessive leakage through open doors or damage to the shelter or because of failure of the primary blower.

A plywood airlock, twenty feet wide, twenty feet high and thirty feet long with full opening access doors was used to permit the passage of all materials, trucks, and cranes. Small doors were installed in the airlock for personnel ingress or egress to avoid using the main doors and two additional emergency exits were also provided in the sides of the shelter.

The inlet air to the blowers was heated by six Herman-Nelson oil-fired heaters which were enclosed in a temporary shelter. The maximum output of the heaters was l-1/2 million BTU/hr. The thin shell does not provide very good insulation qualities and the overall heat transfer coefficient is approximately 1.2BTU/hr/°F/sq.ft. which is similar to single glazing.

The introduction of the heat through the blowers gives good distribution, and as the mass of the structure is low, the internal temperature can be increased rapidly.

The delivered cost of the shelter was just over $50,000 $2.50/sq.ft.

The weight of the supliment was 8706 pounds and occupied a volume of 720 cu. ft.

The shelter was first erected in early February over the excavation for the foundation of the Final Extraction Plant. The temperature ranged from 20° above zero to 22° below zero. The erection was completed within two working days by a crew of sixteen men. No reall problems arose despite the complication of raising the shelter over the large excavation. The structure was completely dismantled,at the end of its useful period, in four hours.

The shelter possesses several advantages over the more conventional types of hoarding, such as:

1) The interior is completely free of posts, trusses, cables, or other supporting members, this allows for more flexibility of operation and construction.
2) The blowers provide a natural circulating media for heat, which is provided by any type of heater located outside the working area. This saves space and also reduces the fire hazards.
3) The skin is translucent and little additional illumination is required during daylight hours. This factor can be a major item for more conventional types of shelter.
4) The structure can be reused, as requird, with no loss of material, as many times as necessary. while the original cost is higher than other types of hoarding, even only a second reuse would be economical.

The disadvantages of the structure must also be considered:

1) Limited working area and height inside the shelter. This is not too serious for small, low buildings, but the work must proceed slower than outside. The handling of material and equipment through the airlock has to be planned and coordinated.
2) The loss of air pressure, for any reason, could be disastrous. All sharp projections on rebar, forms, etc., were covered with a plywood cap to avoid damage to the skin, should the shelter collapse. In good weather, little damage should result, however in a storm (which also

increases the possibility of power failure) the structure could be completely destroyed.

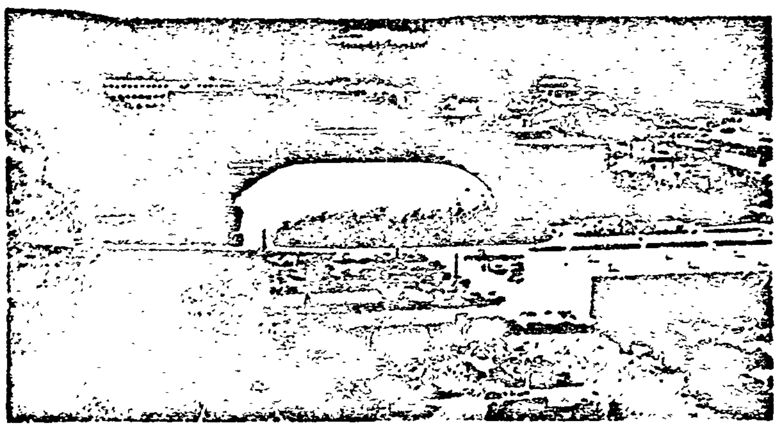


Figure F-1 - View of the 100' x 200' 50' high air shelter. A large vehicle access air lock is at the left end of the structure.

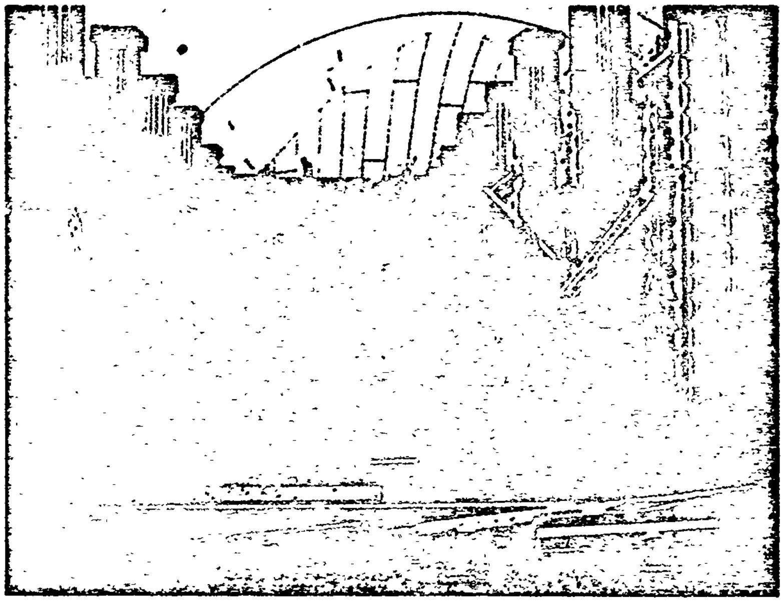


Figure F-2 - Concrete form work in progress inside the air shelter. Note the height of the columns, the wooden caps on top of the reinforcing steel to protect the skin in case of a loss in pressure. Also note the excellent natural light.

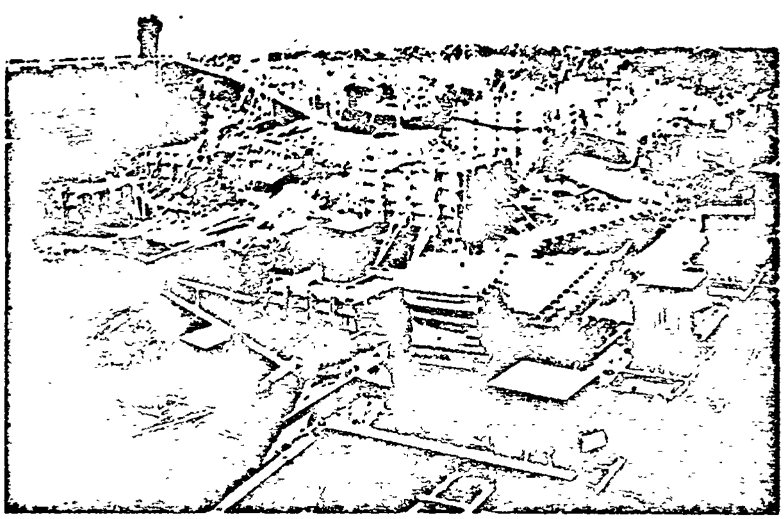


Figure F-3 - An earlier view in the air shelter. Note the trestle supporting the base of the "bubble" over the excavation. The workers in the upper left are standing in front of a small man-made access way.

APPENDIX G
INFORMATION SOURCES

Information on the effects of weather on outdoor worker productivity and methods to provide weather protection was sought through letter contacts with the following:

Trade Associations

1. Associated Builders and Contractors
2. Associated General Contractors of America
3. Building Research Advisory Board
4. Building Research Institute
5. American Concrete Institute
6. American Society of Concrete Constructors

Construction Firms

1. American Dredging Company
2. The Austin Company
3. Bow Valley Industries, Ltd.
4. Bovis Corp., Ltd.
5. Dravo Corp.
6. Dravo of Canada, Ltd.
7. Fluor Corporation
8. General Construction Company
9. J. A. Jones Construction Company
10. Kaiser Industries Corp.
11. M. W. Kellogg (Div. of Pullman, Inc.)
12. Michigan Wisconsin Pipe Line Company
13. Morrison-Knudsen Company, Inc.
14. Guy F. Atkinson Company
15. Blaw-Knox Company
16. C. F. Braun and Company
17. Chemical Construction Corp.-
18. Hoffman Construction Company

19. Whitehead Kales Company
20. Genstar, Ltd.
21. Bechtel Corp.
22. ITT Levitt and Sons, Inc.
23. Pullman, Inc.
24. Ocean Drilling and Exploration Company
25. Ocean Service and Engineering, Inc..
26. The Ralph M. Parsons Company
27. Pacific Car and Foundry Co.

Research Organizations

1. Cold Regions Research and Engineering Laboratory
2. Environmental Protection Systems Division
3. Fordham University
4. National Bureau of Economic Research
5. Naval Artic Research Laboratory
6. Rand Corporation
7. Stevens Institute of Technology
8. U.S. Department of Commerce
9. University of Illinois
10. University of Michigan
11. Department of the Army, Construction Engineering Research Laboratory

REPORT OF THE STUDY FOR DETERMINING THE STATE-OF-ART OF THE USE OF WEATHER PROTECTION IN THE JAPANESE SHIPBUILDING AND HEAVY EQUIPMENT INDUSTRIES.

to
Battelle Pacific Northwest Laboratories

May, 1973

Mitsubishi Research Institute
1-1, Yurakucho, Chiyodaku
Tokyo, Japan

Preface

This is the Final Report on the Study for Determining the State-of-the-Art of the Use of Weather Protection in the Japanese Shipbuilding and Heavy Equipment Industries, based on the Special Agreement B-654, signed on 31st, October 1972, between the Battelle Pacific Northwest Laboratories and Mitsubishi Research Institute.

The study has been carried out according to the principles and definitions stated in the Research Proposal dated 15th November 1972, made by The MRI on the subject above stated. The Draft Report of MRI, dated 27th March 1973, was reviewed by BNW and succeeding comments were meet and incorporated into the Final Report.

Japanese experience on the weather protection for outdoor works are unique and has a history of nearly two decades in many shipyards. Weather Protection facilities in these shipyards are one of the cause of productivity improvement in Japanese shipbuilding industries, competiting in the world market with foreign shipbuilders.

It would be the first time to describe the state-of-the-art of the usc of and the cost-effectiveness of the weather protection devices in Japan in a comprehensive way for foreign people. who have the interest on it.

We hope this Report will be good for the use for the sponsors in U.S.

May 1973

S.Ikeda, General Manager

T. Miyakawa, Senior Transportation Economist

Research and Development Department

Mitsubishi Research Institute,

Tokyo, Japan.

Table of Contents

Tables and Figures in the Report

Tables

Figures

1. The method of study and other explanations

First we have surveyed the usage of weather protection facilities among 25 major Japanese shipyards to get overall picture. Then, we have selected four shipyards, located at places with a wide weather variation and represent different type of workshop layouts, i.e. one from northern region, one from central reagion and two from western region of Japan. We have asked for these four shipyards necessary data for weather protection devices used and carried out enquete survey to engineers at workshops to get data for productivity gains. Photographs were taken on the protection facilities studied during these enquete surveys on the spot.

As for the heavy construction industry wc have selected one large steel construction site located contral region of Japan. We add brief survey of crane and wharf protection during extreme climatic conditions, the data for which were obtained simaltaneously during the survey on the spot.

This study was carried out by us with close cooperations of engineers in the Shipbuilding Division of Mitsubishi Heavy Industries Ltd.

2 Selection of Shipards and a Large-scale Construction site to be Investigated

Pattelle Northwest are requesting to obtain the informations on shipyards, having a range of typical climatic conditions. We set two criteria for the selection of shipyards. The first is the criteria by the climatic conditions and the second is the one concerning the layout of the shipyards.

2.1. The Criteria by the climatic conditions.

The climatic conditions concerning out-door heavy construction works in Japan can be devided into following three types (for detailed explanation on each climate see comments p.9 seq.)

1) Eastern Japan-Pacific Coast
2) Western Japan-Pacific Coast
3) Northern Japan

Whereas the difference in climate between Eastern Pacific Cost and Western Pacific Coast are not so clear except the duration of rainy months during summer, this difference on rainy weather would be significant in considering the out-door working conditions. The climate in Northern Japan differs clearly from the other parts of the country. Despite the relatively low latitude (for example Sapporo, the capital of Hokkaido is at 35°N), the climate there has the same characteristics like Northern Europe, in higher latitude. Thus we need, at least, three types of shipyard that are locating in each of one climatic conditions mentioned aboved.

2.2. The criteria concerning the layout of shipyard.

In Japan there are 45 major shipyards that have at least one shipbuilding berth over 5,000 gross tonnage. Among these, 23 shipyards have been building the major part of new ships. These 23 large shipyards that have at least one building berth over 30,000 gross tonnage, can be divided into 3 groups in terms of the date of their establishment.

First group of shipyards arc old ones that were established before or during the World War II and some of them even dated from one hundred years ago. The layout and the construction flow of these old shipyards have been modernized and renewed as possible within the limited land use after the War, especially during the Suez Crisis shipbuilding boom, (1956-58), and the second boom after 1963.

The second group of shipyards are completely new giant shipyards that are established upon the reclaimed land, and its layout were designed to achieve the most effective construction. These shipyards were erected mainly after 1965. Whole of them have building docks that can build super tankers over 100,000 gross tonnage.

The third group is the most newly established and the largest shipyards. They have large building decks in which tankers up to one million dwt can be built. They began their operation around 1970.

The types of weather protection devices used among these shipyards depend on the differences of the duration of operations since shipyard's establishment and subsequent modernization and their final layouts.

2.3 The differences of the use of weather protection devices among the type of shipyards.

In Japanese shipbuilding industry, the means to prevent the fluctuation of productivity in the outdoor welding and assembling works due to the variation of weather, have been improved significantly during these decade.

In the most old conventional type of shipyards, the outdoor works in hull construction yard were changed and arranged to fit into the large welding and black assembling factory during the later half of 1950's. In the case of Nagasaki shipyard (Mitsubishi Heavy Industries), these improvements were carried out through following process.

(1) change of the flew of sheets
(2) modernization of sheet bending and cutting process
(3) enlargement of welding spaces
(4) increase of crane capacities
(5) construction of huge roof overwelding and small block assembling yard
(6) integration of welding work and small-block assembling work

At the end of covered assembling factory, hull blocks, usually SO to 80 metric tons in average, were lifted up and down directly onto the adjacent building berths by the giant gantry cranes. Thus the most parts of hull construction stages were covered by the roofs cxcept final assembling processes that were carried out on the building berths. These improvement, which included the change of factory layout partly, was completed by the end of 1957, when the ratio of outdoor works was reduced to only 14 percent to the whole hull construction works. The layout of building berths were changed again substantially during 1965-68 to enlarge building capacity at Nagasaki. These improvement consisted of the integration and increase of width of old berths, replacement of old gantry cranes to giant goliath cranes and construction of new building docks. The crane capacities were increased from 50 tens to 120 tons and thus the maximum size of blocks to be supplied from the assembling factory reached up to 120 tons. However major flow of hull blocks remained, in principle, the same as before.

These "indoorization" of outdoor welding and assembling works were carried out, in general, through similar processes in other major shipyards on the Pacific Coast during 1955-1965.

The plannings and constructions of the new shipyards in the second group began around 1960 among the largest shipbuilding companies. In this case, some of the Swedish examples of advanced shipbuilding technology and novel ideas incorporated into the layout of ships within shipyards, e.g. those at the Arendal Shipyard of Gotaverken A/B, had a considerable influence upon the planning of new larger shipyards in Japan. In these new generation of shipyards, the most part of outdoor works were "indoorized" from the beginning, having large welding and block-assembling shops. For example, in Yokohama Shipyard of Ishikawajima-Harima Heavy Industries Co., Ltd., there arc five indoor welding and block-assembling shops, each 853 feet long and 115 ft. wide. Hull block over 100 tons can be assembled in these shops. The outdoor works remains only at the final assembling stage on the uncovered building dock. This New Yokohama shipyard of IHI began its operation 1968.

In the third group of new shipyard, even the large building dock is covered partly by the roof. For example, in Koyagi Shipyard of Mitsubishi Heavy Industries, the maximum size of a hull block which can be assembled within assemble shops arc 600 tons. Over the buildingdock, that is 3182 ft. long and 328 ft. wide, there are two sets of travelling roofs each 164 ft-long and 328 ft. wide. Thus, the works in the final stage of ship-construction are partly "indoorized". This newest shipyard has just begun its operation in this year.

2.4. The Selection of shipyard

We select three large shipyards each located in different climatic conditions from layout type 1, that is Shipyard W from Eastern Japan, Shipyard X from Western Japan and Shipyard V at Northern Japan. For the method used in the indoor welding assembling works in the type 2 shipyards are the same to those are used in the type 2, we do select no shipyard from the layout type 2, However we add Shipyard Y from layout type 3. (cf. Table 1),

Although we will survey the use of weather protection facilities in these four shipyards in deptth, we supplement the result with further informations on other shipyards, if we find significant exceptional examples to the fact surveyed.

Table 2-1 Classification of Shipyards. (1) (2)

Type of Layout / Climatic Condition	Type I. Old but modernised	Newly Built large Shipyard: Type II.	Newly Built large Shipyard: Type III.
Eastern Japan	IHI-Tokyo, IHI-Nagoya, MHI-Yokohama NKK-Tsurumi Sumitomo	Mitsui-Chiba IHI-Yokohama	NKK-Tsu
Western Japan	IHI-Kure IHI-Aioi MHI-Nagasaki MHI-kobe MHI-Hiroshima Kawasaki-Kobe Mitsui-Tamano Hitachi-Innoshima Osaka Sasebo	Kawasaki-Sakaide Hitachi-Sakai	MHI/Koyagi
Northern Japan	Hakodote Hitachi-Maizuru		

Note (1) Major 23 shipyards are listed first by the name of company and then of shipyard, i.e. IHI-Tokyo means Ishikawajima-Harima Heavy Industries, Tokyo Shipyards.

(2) Abbreviation of the names of companies,

MHI: Mitsubishi-Heavy-Industries

NKK: Nippon Kokan Company

Table 2-2. Shipyard to be studied in Depth.

region	name	shipbuilding capacity
northern	shipyard V	43.700 G.T.
central	shipyard W	106.000 G.T.
Western	shipyard X shipyard Y	170.000 G.T. 250.000 G.T.
Large-scale construction shop	workshop Z	———

A rough distribution of shipyards under study is shown in the figure 1.

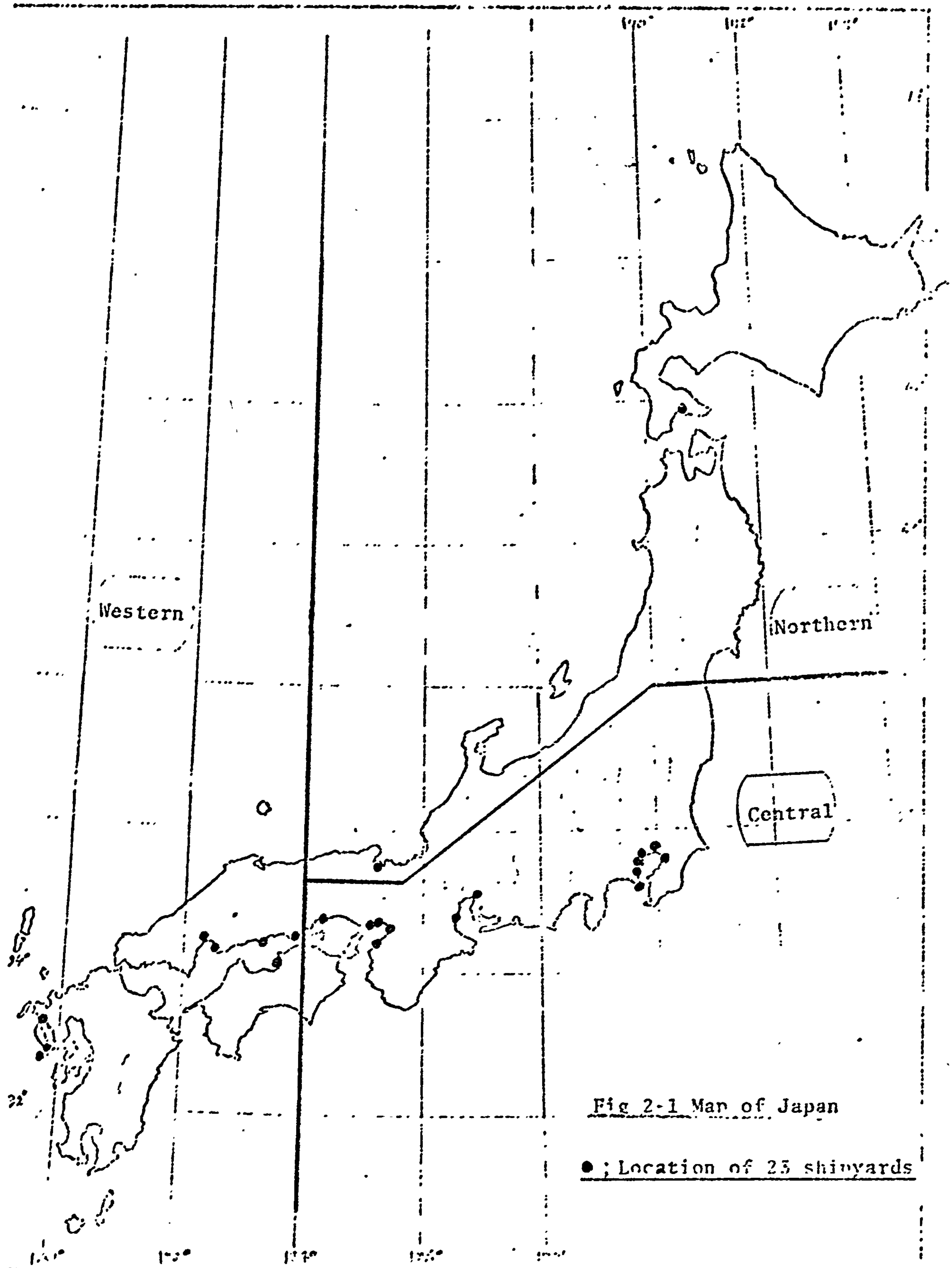


Fig 2-1 Map of Japan

● ; Location of 23 shipyards

3.1. Two Patterns in Climate

Japan consists of islands, facing eastwards to the Pacific Ocean and westwards to the Sea of Japan. Japan also has a latitudial span of 21, from 24°N to 454. llence, there are-two different climatic conditions in Japan. The first, which we call "climatic pattern of emote Nippon", forward side of Japan, i.e. Pacific Coast, except northern Tohoku, North eastern region of Honshu, and Hokkaido, has a similar chracter of weather It is hot and moist in summer and relatively warm and dry in winter. In June and first half of July we have usually the rainy season due to the monsoon from the Asian Continent. But in winter, we have relatively stable weather. It is fine and rarely rains or snow.

The second pattern that we call "climatic pattern of Ura Nippon", back side of Japan, i.e. regions along Sea of Japan and llokkaido. The weather in summer is not so different from "Omote Nippon", but in winter there are many snowy days. It is cold and dark from November to March. From December through February the temperature is below freezing point in Hokkaido. In this region, "the rainy season in June and July" is not so distinct. We explain these differences in details constracting with the number of the days of rain and snow and temperature and precipitation at four cities.

3.2. Temperature

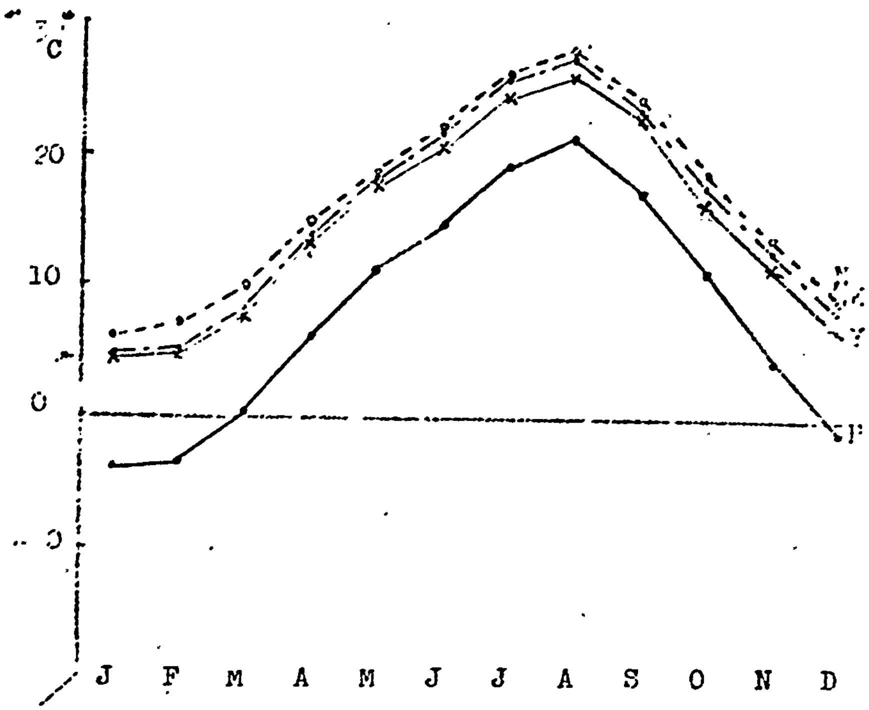
In temperature significant difference can be observed between Hakodate (Hokkaido) and other three cities in Honshu. In Hakodate average temperature through year is under 10°C and during winter, monthly average are below freezing point.

month	Hakodate	Yokohama	Kobe	Nagasaki
1	-3.9	4.4	4.5	6.2
2	-3.5	4.8	4.8	7.1
12	-1.1	7.0	7.4	8.9
average	-2.1	6.0	6.2	8.1
7	19.3	24.6	25.8	26.4
8	21.5	26.1	27.3	27.6
9	17.2	22.6	23.6	24.3
average	17.5	24.4	25.6	26.1

(Obsevation data: 1941-70)

Fig 3-1

temperature (average, 1941-1970)



H: Hakodate
Y: Yokohama
K: Kobe
N: Nagasaki

3.3 Precipitation and Wind

Monthly change in precipitations at four cities are shown in Fig 2. The peak due to the monsoon is in June except in Hakodate. The second peak in September are usually due to the typhoons. The largest precipitation is observed at Nagasaki. (cf. Table 1)

Table 3-1 Precipitations

	average precipitation per month millimeters	(inches)	precipitation per per year millimeters	(inches)
Hakodate	95.3	(3.75)	1143	(45.0)
Yokohama	136.0	(5.35)	1632	(64.3)
Kobe	113.9	(4.48)	1367	(53.8)
Nagasaki	164.7	(6.48)	1976	(77.8)

Table 3-2 Days of Rain and Snow

Month / Place	J	F	M	A	M	J	J	A	S	O	N	D
Hakodate	11 (9)	11 (10)	9 (7)	3	4	4	4	3	4	6	6 (3)	11 (9)
Yokohama	3 (1)	4 (1)	4	5	4	6	3	3	4	6	4	2
Kobe	3 (1)	4 (2)	4	3	4	6	4	2	5	5	3	3
Nagasaki	5 (3)	5 (1)	5 (1)	4	5	7	5	2	4	3	2	5 (1)

(Observation Data: 1945-52)

Note: Figures in brackets show the days of snowfall.

Fig. 3-2

Precipitation and Temperature

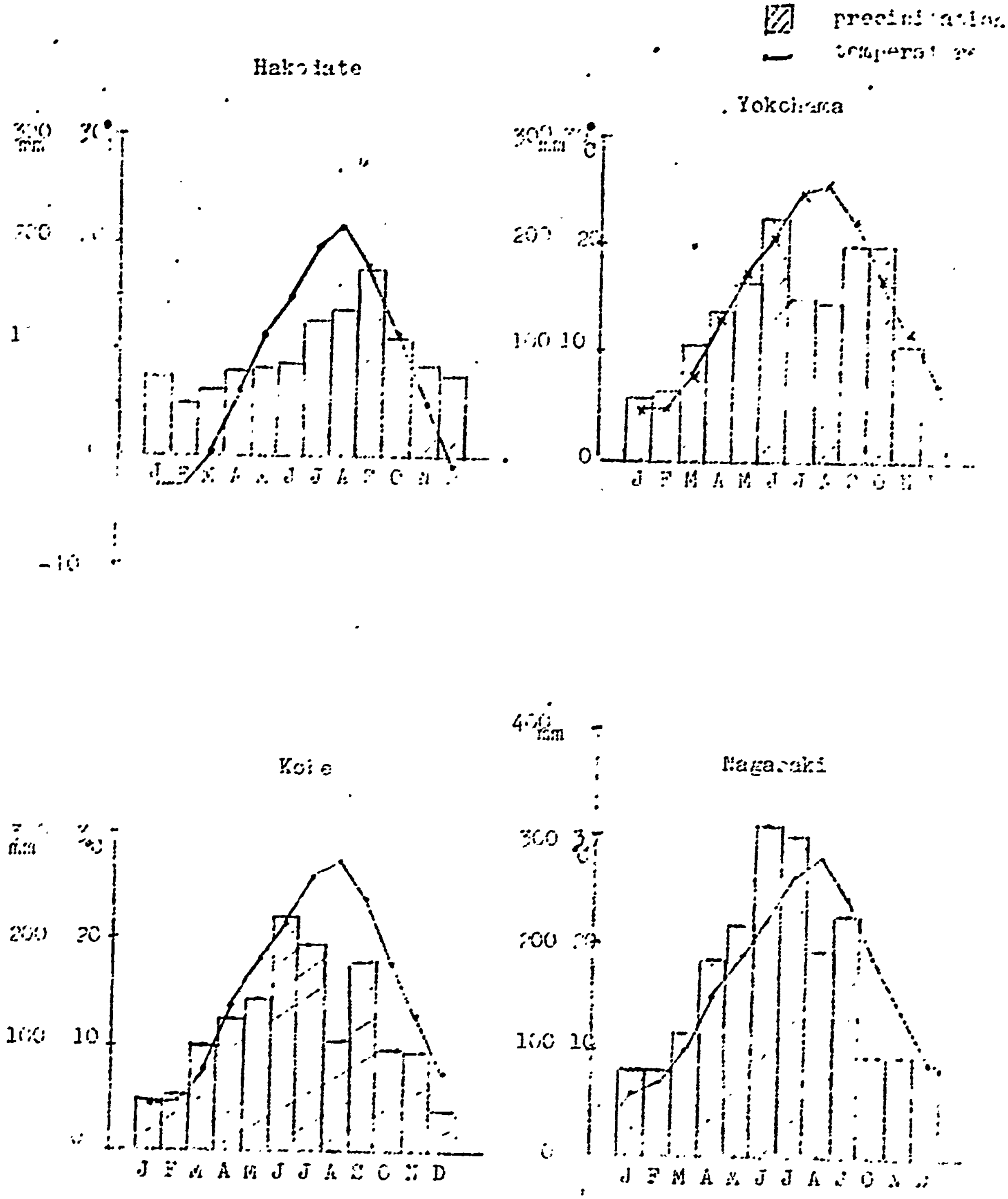


Table 3-3
The amount of snowfall (Depth of snowfall of each month is designated by number of days in each category)

month / region	Categories of depth of snow (inch)	11	12	1	2	3	4	total
Western	under 3.94	0	0	2	1	0	0	4
	over 3.94	0	0	0	0	0	0	0
	over 7.87	0	0	0	0	0	0	0
	over 19.69	0	0	0	0	0	0	0
Central	under 3.94	0	0	1	3	1	0	5
	over 3.94	0	0	0	1	0	0	1
	over 7.87	0	0	0	1	0	0	1
	over 19.69	0	0	0	0	0	0	0
Northern	under 3.94	6	14	7	5	10	2	45
	over 3.94	1	9	24	22	11	0	67
	over 7.87	0	4	14	16	7	0	41
	over 19.69	0	0	0	0	1	0	1

(Values above are averages between 1941 and 1960)

Table 3-4
Temperature (in centigrade) (during the work hours)

month / region	1	2	3	4	5	6	7	8	9	10	11	12
Western	6.2	7.1	10.2	14.7	18.5	21.9	26.4	27.6	24.3	18.6	13.8	8.9
Central	4.4	4.8	7.5	12.7	17.1	20.5	24.6	26.1	22.6	16.5	11.5	7.0
Northern	-3.9	-3.5	0	6.1	11.0	14.8	10.3	21.5	17.2	11.3	4.6	-1.1

(Above values are averages between 1941 and 1970.)

Table 3-5
Wind Velocity (during the work hours)

month / mph / region		1	2	3	4	5	6	7	8	9	10	11	12
Western	22.4 -33.6	8	7	9	7	6	7	7	3	4	3	3	5
	over 33.6	1	1	2	2	1	2	2	1	1	1	0	1
Central	22.4 -33.6	15	15	16	16	14	9	8	7	8	12	11	12
	over 33.6	3	4	4	4	2	1	1	1	2	2	2	3
Northern	22.4 -33.6	15	14	16	16	14	7	4	3	7	10	11	13
	over 33.6	3	3	2	2	2	0	1	0	1	1	1	2

(Above values are averages between 1949 and 1960)

Table 3-6
The number of days of high discomfort index (during the work hours)

month	June			July			August			September		
Discomfort index / region	75	80	85	75	80	85	75	80	85	75	80	85
Western	9.0	0	0	30.0	14.4	0.4	30.8	18.2	1.2	19.4	4.8	0
C ntral	8.4	1.2	0	24.4	8.4	0	27.2	17.2	0	13.8	4.4	0.2
Northern	0	0	0	1.6	0	0	6.0	0	0	0.4	0	0

(Above values are averages between 1956 and 1960)

note:

discomfort index=o.72x(temperatures + wet-bulb temperatures) + 40.6

We feel rather discomfort when the index shows over 70 and very discomfort when it shows over 80.

Table 3-7

The number of days with outdoor temperatures below zero at the shipyard V.

The time of measurement: 9.00A.M., 12.00A.M., 3.00P.M. Measurment was made at above three time points and the average was taken of the three values.

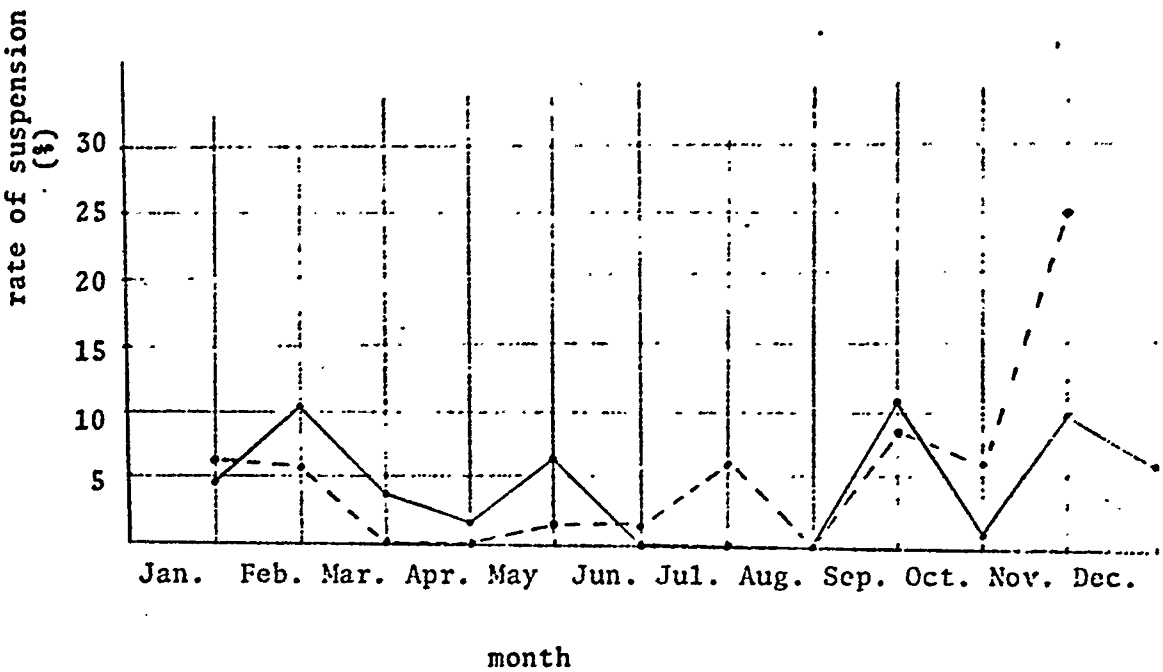
month	The number of days with temperatures below zero					total
	28.4F	24.8F	21.2F	17.6F	14F	
Nov. 1969	3	0	1	0	0	4
Dec. 1969	9	5	3	0	0	17
Jan. 1970	8	3	2	2	1	16
Feb. 1970	10	6	3	1	0	20
Mar. 1970	4	7	1	1	0	11
Nov. 1970	2	0	0	1	0	3
Dec. 1970	5	2	1	0	0	8
Jan. 1971	5	5	3	1	0	14
Feb. 1971	7	2	3	0	2	14
Mar. 1971	5	0	0	0	0	5
Nov. 1971	1	0	0	0	0	1
Dec. 1971	3	2	0	0	0	5
Jan. 1972	10	4	2	0	0	16
Feb. 1972	7	2	1	1	0	11
Mar. 1972	4	1	0	0	0	5

Table 3- 8

The record of wind velocity in recent times at the shipyard V

month	the number of days of operation	the number of days crane operations were stopped	the number of days warning index issued against crane operation	remarks
Jan. 1971	22	1.0	3.0	
Feb. 1971	23	2.5	1.0	
Mar. 1971	27	1.0	3.0	
Apr. 1971	23	0.5	5.0	Warning is issued against crane operation when wind velocity reaches 33.6 to 40.3 miles per hour.
May 1971	21	1.5	3.0	
Jun. 1971	26	0	0	
July 1971	26	0	0.5	
Aug. 1971	25	0	2.5	
Sep. 1971	22	2.5	4.0	
Oct. 1971	26	0.5	4.5	
Nov. 1971	25	2.5	4.5	Crane operation is stopped when wind velocity is more than 40.3 miles per hour.
Dec. 1971	25	1.5	2.5	
Jan. 1972	23	1.5	4.0	
Feb. 1972	25	1.5	3.5	
Mar. 1972	25	0	1.5	
Apr. 1972	21	0	2.5	
May 1972	22	0.5	2.5	
Jun. 1972	25	0.5	4.0	
Jul. 1972	25	1.5	2.0	
Aug. 1972	26	0	2.0	
Sep. 1972	24	2.0	2.0	
Oct. 1972	24	1.5	4.5	
Nov. 1972	24	6.0	2.0	
Dec. 1972	-	-	-	

Fig. 3-3.
The monthly rate of suspension of crane operation



note: 1) The solid line designates the curve for 1971, while the dotted line designates the curve for 1972.

note: 2) The average rate for 1971......5.7%
The average rate for 1972......4.6%

note: 3) Monthly rate of suspension of crane operation is defined here as the ratio of number of days when crane operations were stopped to the number of days of operation (cf. Table 3-8 in the previous page).

4. Actual Condition. of Protection Facilities in Japan

There are four type of weather protection facilities, adopted for outdoorworks in shipyards and heavy construction industries, i.e. (1) roofs, (2) other facilities in workshops, (3) special devices for cranes and (4) those for wharfs.

4.1. Roofs

Covering with roofs is one method to provide protection from wind, rain, snow and heat. There are four types of roofing and their specifications are described roughly in the Table 4-1.

Table 4-1. Type of Roofing

Type	Specification
Permanent building, fully closed	Steel frame roof covered with galvanized iron sheet
	Steel frame roof covered with long precoated iron sheet
Permanent building with traveling roof	Steel frame roof covered with galvanized iron sheet or long precoated iron sheet
	Steel frame roof covered with slate
Permanent building with roof, not fully closed	Steel frame roof covered with galvanized iron sheet
Simple traveling roof	Light gage steel frame roof covered with galvanized iron sheet
	Lightweight steel tube roof covered with eslon sheet

Table 4-2.

Covered rate of assembling yard in major shipyards in Japan mainly as of 1970.

Region	Shipyard	Covered rate (%) total	type 1	type2	Remarks
Northern	V	56	42	14	
	A	51	51	0	type 1 100%, as of April 1972
	B	52	17	35	
	W	47	29	18	type 1, 37%
	C	84	76	8	type 2, 33%
	D	100	100	0	total 70%,
	E	59	42	17	as of April '72
	F	34	0	34	
Central Japan	G	56	25	31	type 1, 49%
	H	68	36	32	type 2, 21%
	I	96	96	0	total 70%,
	J	34	34	0	as of April '72
	K	27	16	11	
	L	49	7	42	
	M	61	61	0	
	N	62	0	62	
Western Japan	O	90	90	0	
	P	60	49	11	
	Q	100	100	0	
	R	87	87	0	
	S	72	61	11	
	T	55	20	35	
	X	67	64	3	
	Y	100	100	0	as of April '72

Note:

(1) covered rate (%) of assembling yard

$$= \frac{\text{Square meter of indoorized assembling surface}}{\text{Total square meter of assembling surface}} \times 100$$

(2) Type 1: covered by fixed roof, type 2: covered by travelling roof.

Among four production stages in new construction work, Steel Fabrication stages are wholly indoorized. The vital parts of Block Assembly stage are covered by roofs in the most shipyards. The covered rate of workshop is outlined below.

Block Assembly Shop: Covered ratios by roofs range from 51 to 100% in shipyards.

Pre-Erection Shop, Dock and Builking Berth: Almost all shipyards have no protection facilities, except for several new shipyards provided with roofs of a covered ratio of about 10%. This may also apply to constructional steel works. Painting and Coating Shop: Traveling and fixed roofs are used in roofed shipyards and constructional steel works, with covered ratios ranging from 60 to 100%.

The data of the roofs actually installed at four shipyards surveyed in depth, are shown in the Table 1-5 in the Appendix 1 and their photograph as No. 1-12 in the Appendix 2.

The fiscal 1970 survey on covered ratios in block assembly shops Of Japan's principal shipyards (Table 4-2 on previous page.) gives the following covered ratios: (1) 27 - 87% for shipyards built prior to 1960; (2) 51 - 99% for those built from 1961 to 1970 ; and (3) 100% for those built from 1971 up to now. According to the survey made this time in 1972, covered ratios of block assembly shops in shipyards in (2) have increased to 70 - 100%. This means that introduction of flow production systems like coveyor lines to promote automation and labor saving in block assembling has necessitated roofing. Particularly, all of newly constructed, sophisticated shipyards In the central and western parts are fully roofed regardless of their siting and weather conditions.

4.2. Other Protection Tools

4.2.1. Needs for personal protection tools

Conditions for which needs for personal protection arise in winter and summer are as follows:

Winter: In the northern part, leather windbreakers and trousers are supplied to all outdoor welders for protection from cold while in the central and western parts outfits for protection from cold are lent to several thousand outdoor workers. Each workshop has heating devices installed as required to allow workers to warm themselves. However, no measures for protection from cold are taken in workshop which arc not covered completely.

Summer: Since the maximum temperature in the year (monthly average) is 70.7°F, most comfortable to the human body, in the northern part, no protection from heat is provided there. In the central and western parts indirect methods such as fans and coolers and direct methods like cool suits are taken.

4.2.2. Specifications of protection tool for personal use.

There are five main items in protection tool, i.e. ventilating fan, cooler/heater, water cooler, clothing and material to make shadow.

Applications of such protection tools and equipment are listed below.

Table 4-3 Protection Tools and Equipment

Item	Location	Specification
Ventilating fan	Block assembly shop Pre-erection shop Building berth and dock Painting and coating shop	Commercially available motoroperated venti-lating fans 5 - 30 KW
Cooler and eater	do.	Inboard cooler with the same performance as commercially available type 33 KW
		Gas and kerosine stoves are used as heaters
		Coke stove are used as heater
Water cooler	do.	Commercially available types are used
Outfit for protection against cold	Outdoor block assembly shop, building berth and dock in welding	Coat and vest for pro tection against cold
		Leather windbreaker and trousers and pocket warmer

-cont'd-

-cont'd-

Net for protection against heat	Building berth and dock Pre-erection shop	Made of nylon and sized 269 to 1076 sq. ft.
Cool suit	Pre-erection shop Building berth end dock	Compressed air is fed into bag in vest to cool

4.2.3. Use of protection tools among shipyards

We surveyed the state of the arts of the use of protection tools for personal use among 25 major shipyards in Japan, using the data made by Nihon Zosen Kogyokai (Shipbuilders Association of Japan). The data were revised by us through direct interview or questionning to get up-to date picture in Jan. 1972. Percentages in the following Tables denote the share of the number of shipyards in which particular tools adopted to the total number of shipyard surveyed, otherwise mentioned.

Diffusion of use of Protection devices for variation of temperature in the major Shipyards, in Japan as of January 1972 is as follows.

A. Heating

Table 4-4. Adopted Types by shipyard (25 shipyards)

Types \ Shops	Steel Fabrication	Assembly	Dock and Building Berth
Steam heating	0	0	0
Warm air blower	0	0	0
Gas Stoves	8	5	3
Electric heater	1	0	0
Coal stoves	0	6	1
Oil heater etc	15	10	11
nothing	1	4	10

Table 4-5. Wearings

	percentage of adoption among 24 shipyards
Winter cloths	83%
Portable body warmer	42%
Winter waistcoat	12%
Anorak	4%
Muffler	4%
Ear-cover	4%

Table 4-6. Standard and system of Supply

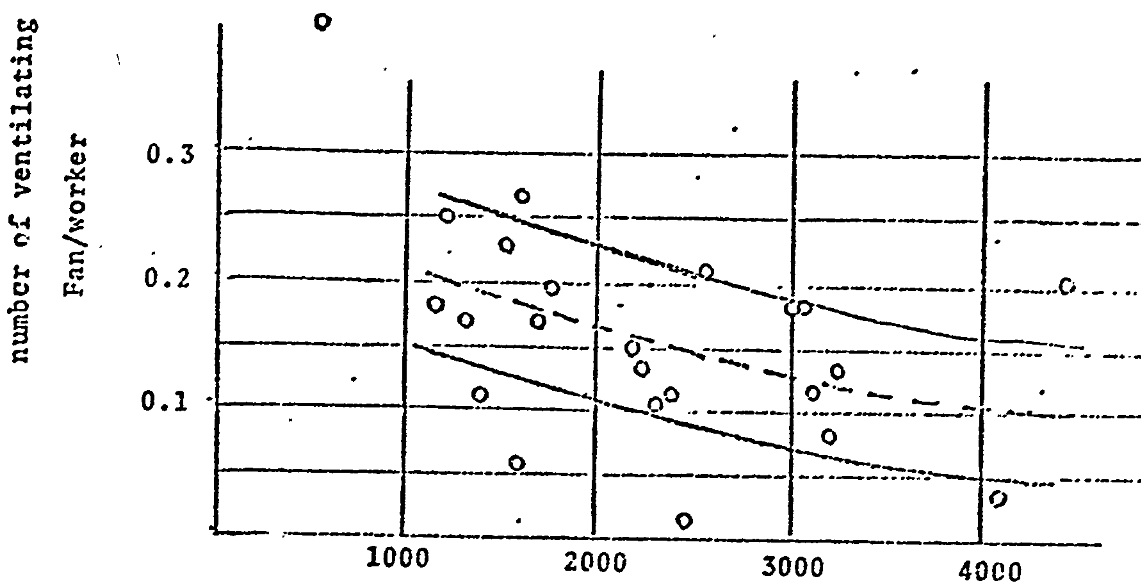
For those who work outdoor wholeday	37%
For workers at building berth and dock during over-time work at night	25%
For outdoor crane operators at night	4%
For all outdoor workers	46%
Lending system	71%
Supply as personal effects	17%

B Cooling (for 23 shipyards)

Ventilation Fan

Ventilation Fans are used widely among shipyards, of which two standard types are shown as photographs 13 and 14 in the Appendix 2. The correlation of number of ventilating fans instalied and the number of workers served are shown in Figure 4-1.

Figure 4-1.Number of ventilation Fan installed



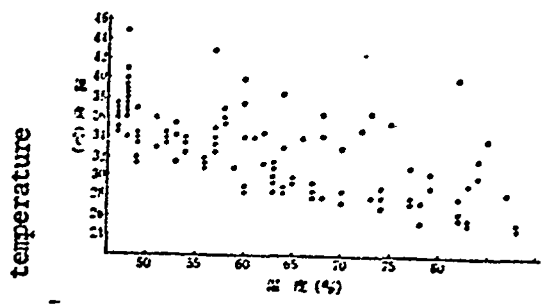
number of workers served

Spot Coller Unit

In some shipyard, Spot Cooler Unit, which is shown as photograph 16 in the Appendix 2 , arc used to blow cool air through ducts into the shop or into the tank block of-ships on the dock. The complete encolsure of ways do arise other kinds of extreme environments. These arc high temperature, moisture, noise and dust. For example, in welding and fitting works in large hull blocks on the docks in summer, people sometimes have to work in as high temperature as 104F and in high moisture

over 80 percent. These hot and moist environment are caused by the radiation heats both from the equipments themselves people using, i.e. gas cutters, welding tools etc., and steel sheets hot up by direct sunshine. We show an example of high temperature and moisture observed in the hull construction works in Japan.

Figure 4-2. Temperature and moisture in the holds and tanks on the dock.



moisture

source: Shipbuilding Association of Japan
Working Environment Committee.

These temperatures and moistures are usually extremely high in the holds and tanks directly under the deckplates and inside of side shells in summer. To protect welders and strain removers who are working under such an extreame conditions, Spot Cooler Unit are available in several shipyards. (cf. Figure 4-3). The effects of this device at the shipyard W in the Central Japan and the shipyard X in the Western Japan in the summer 1972 are shown in the Table 4-5. Temperature decrease was 37.4°F in average, moisture decrease 3-5% and discomfort index was lowered to 80.

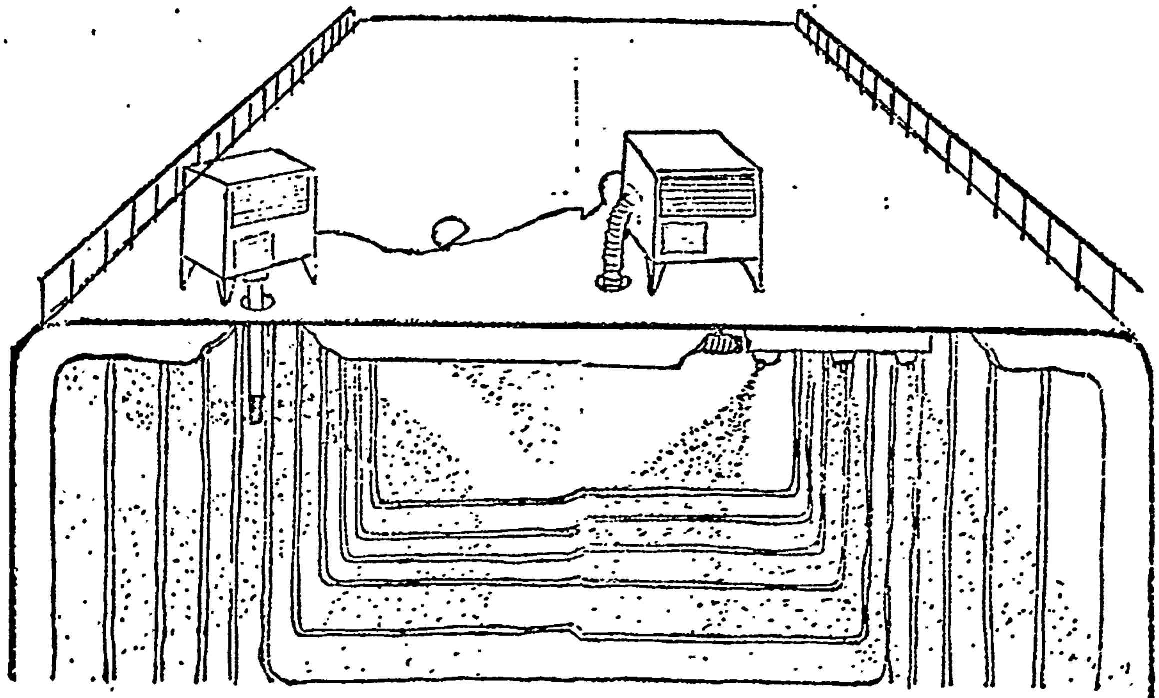
Table 4-7. The effects of Spot Cooler Unit in the Tanks and Holds.

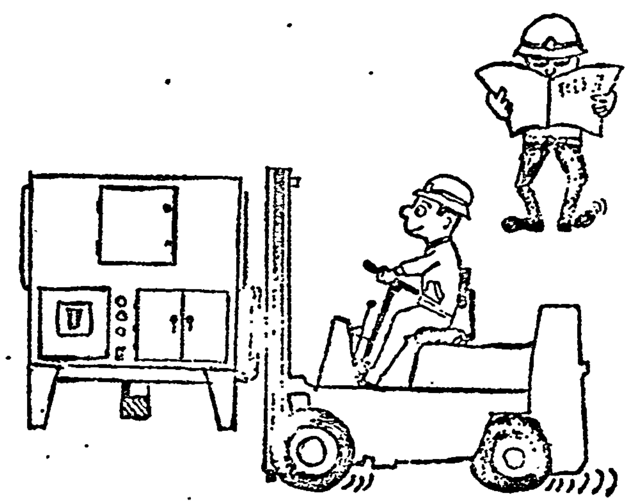
Ovserved: middle of June—middle of September 1972.
(Shipyard W in Cemtral Japan)

middle of June—middle of October, 1972.
(Shipyard X in Western Japan)

item / region	temperature °F				humidity %				discomfort index			
	air on the deck	(1)no air cooler	(2)air cooler	(1)-(2)	air on the deck	(3)no air cooler	(4) air cooler	(3)-(4)	air on the deck	(5)no air cooler	(6)air cooler	(5)-(6)
Central	93.2	95.0	89.6	5.4	47	47	44	3	84	85	80	5
Western	89.6	100.4	91.4	9.0	66	47	42	5	82.5	88	81.5	6.5

Figure 4-3. Spot Cooler Unit on the deck plate





Other devices

In all 23 shipyards surveyed, sunnet are used to make shadow to protect workers under direct sunshine on the outdoor working shops (cf. photograph 26 in the Appendix 2.)
In some shipyards dry ice is supplied to the outdoor workers to prevent the heat, especially to cool their heads.
They put the packed dry ice in the bag of felt and set it in the helmet. They change it. twice a day, that is, in the morning and in the afternoon. However the use of dry ice has been suspended recently in many shipyards.

The cool suits is shown as photograph 19 in the Appendix 2.

Table 4-8. Other devices

	Percentage of adoption among 23 shipyards surveyed
Sunnet	100%
Supplying dry-ice for personal use	31%
Vortextube and cool-suits	52%

4.3. Cranes

To prevent cranes from speeding and overturning due to wind force, all outdoor cranes are equipped with clamping devices regardless of their size. (Installation of this device is required by regulations of the Japanese Government.) There are four types of crane protection method, of which photographs attached in the Appendix 2, as follows.

Type I. Rail clamping (photos. No. 20)
Type 2. Hooking (photos. No. 21.22.)
Type 3. Pin drop (photos. No. 23.24.)
Type 4. Guy wire (photos. No.25)

Though different depending on type of crane, these devices may be roughly divided as listed below.

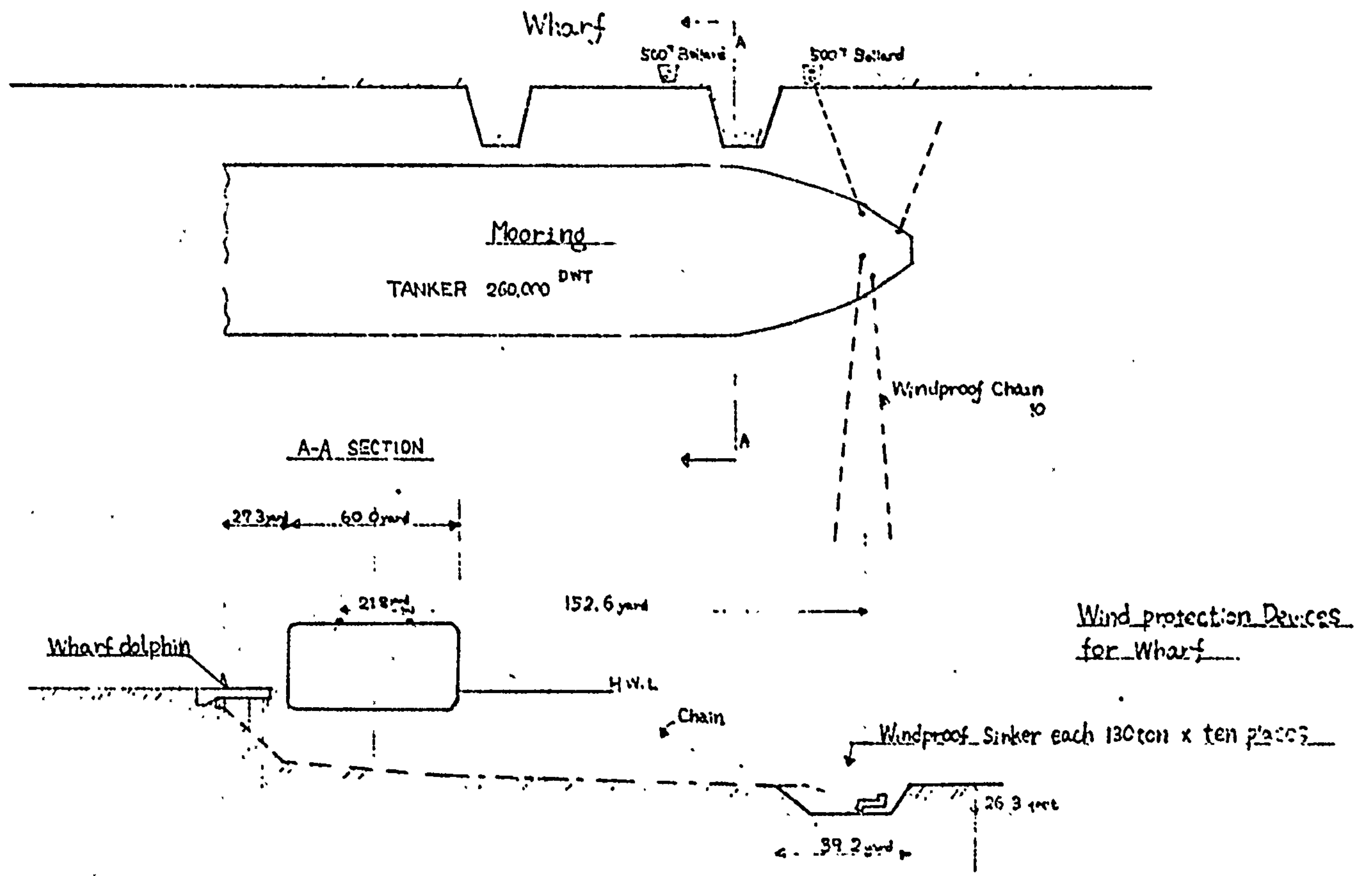
Table 4-9 Crane protection methods

Description	Specification
Rail clamping System	Crane rail is clamped with steel clamp near crane saddle
Hooking system	Steel hook provided on underside of crane saddle is fitted into eye provided outside or inside of crane rail to clamp crane
Pin (Drop-in) system	Steel bar or strip pin equipped on outside of crane saddle is put in hole provided in foundation outside of crane rail to fix crane
Guy wire system	Steel wire a steel turnbuckle is used to fix crane to foundation from outside of crane saddle

4.4 Wharf

Almost all shipyards have no particular provisions against strong wind, except for some newly built shipyards in which windproof sinkers arc equipped, provided there are ample open sea in front of wharf. An example of the windproof sinker at Shipyard Y is shown as Figure 4-1. Ten chains fixed at the bottom of open sea can hold a mooring ship with other ten chains on wharf side in the case of strong winds.

Figure 4-4. Windproof sinker at Shipyard Y.



5. Relationship of Weather Variation to Productivity in Japan

5.1 Background of the survey

We defined, here, productivity as man-hour efficiency,i.e, man-hours consumed per unit volume of construction. This productivity measure is generally used, as basic index for daily and monthly production control in. Japanese shipyards. The productivity is influenced by equipment, personnel composition, management organization and construction method; of which latter two factors are based on the former two. Weather conditions have also influences on the productivity as a whole. This makes it difficult to single out precise relationship of weather variation to productivity change.

We have tryed to find statistical correlations between man-hours consumed in particular workshops and weather variations during certain time span. Here, productivity measured mainly by man-hours, is a function of weather variations, method of production and management and two factors for production, i.e. equipments and labour. However, man-hours consumed per unit volume constructed differ ship by ship due to their type and size. If we took the man-hour data on the same type and size of ships in longer periods, say four and five years, the production methods were improved gradually during these years. Thus we could not find any precise correlation statistically between weather variation and man-hours consumed.

When we have carried out surveys in depth at four shipyards selected, we have asked for over fifty supervisory personnel at various managerial levels who havc long experiences in production work, on their opinions on the effect of weather variations on productivity. Replying to this question, some one relies on man-hours data and others on different data they are using according to their types of workshop. We asked for them to express their empirical obsevations on the effect of weather variations in terms of percentages.

5. 2 Degree of Effect of Weather Change

The degree of effects of weather change on productivity, based on the empirical observation thus collected, is shown in Table S-1 . In this table, the monthly degree of effects on productivity are shown as percentages of monthly production in each region compared with the best production efficiency observed from the past experience. This best efficiency is for the production activity of shipyard as a whole, not for the outside work only. Although the effects of weather variation are naturally the lagest on outside works, the production efficiency in roofed Block Assembly Shop has to be reduced, if there occur slow down due to weather variation in succeeding working stage, i. e. Pre-Errection

The most shipyards in Japan are usually located at relatively narrow site along old ports, for example Nagasaki port is older than United States itself, i,e. it had been receiving foreign traders since 17th century. When Commodore Perry asked for Tokugawa Shogunate Government to open several Japanese ports for U. S. merchant marines 120 years ago, Yokohama, Kobe and Hakodate were in his list of ports to open doors to him. In old shipyards located at such historically old ports, there are scarcely ample spaces between workshops for storing stock and members to adjust the difference of production efficiencies if any, among workshops. The slow down of production at

Pre-Errection and Dock/Building Berth inevitably affects the production pace of Block Assembly Shop. The effect of weather variation should not be considered separately for outside work only. Thus the figures shown in the Table 4-9 denote the effects of weather change observed as a whole for each shipyard, based on the experiences and opinions of fifty managers and supervisor interviewed.

At the shipyard in northern region, monthly productivities arc reduced to 85% to those in best conditions during winter, from November to March. These reduction are mainly caused by low temperatures and snows. The work dots not stop in the cold days below 0°C, however it is impossible to estimate the reduction of efficiency due to cold temperature. Further, snow removal on uncovered surface needs another costs. Based on the data of the past few years, the costs of snow removing works arc as follows.

For total surface	\$ 362/100yd^2
of which for-assembly	\$ 162/100yd^2
of which for-welding work	\$ 200/100yd^2

Table 5-1
Degree of Effect of Weather Change on Productivity by Region in Percent

Month / Region	1	2	3	4	5	6	7	8	9	10	11	12	annual average
Northern	85	85	85	90	90	95	100	100	95	90	85	85	90
Central	95	95	95	100	100	100	85	85	85	100	100	95	95
Western	95–97	95–97	100	100	100	90	85	85	85	100	100	95–97	95

Note : 100% denotes the best contitions in each region

Table 5-2
Seasonal Division by region

Month / Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern	Winter →					←	Summer		→		←	Winter
Central	Winter →						←	Summer	→			Winter ←
Western	Winter →				←		Summer		→			Winter ←

In the Shipyard W in Central region, the effect of weather variation, are usually the largest in summer, expecially due to the high temperature and moisture (of. Table 3-5) and partly due to rain. Monthly productivities during summer arc reduced to 85% to the best efficiencies.

In the shipyard X in Western region weather conditions and its effects on productivity arc almost the same as the Central region, except precipitations during summer months.

The effect of weather variations to the best production efficiencies, considered in annual average percentage, are 10% at shipyard in Northern region and 5% at shipyard W and X in the Central and Western regions.

5-3 The Secondary Cost Effect

There is no direct correlation between accidents rate and extreme environment in Japanese shipyards. Here accident rate is defined as the frequency of accident, for which worker has to absent himself from work, to one million working hours. The frequency observed at shipyard W and X in Central and Western regions in shown as Table 5-3 . Accident rates are rather high in a fine and comfartable day like spring afternoon. People ususally seem to be more cautious to protect themselves in the extreme working conditions.

Table 5-3 Accident frequency at Shipyard W and X 1972.

Month	J	F	M	A	M	J	J	A	S	O	N	D
Accident Frequency	6.35	5.01	10.87	5.20	2.35	0	0	0	0	0	0	2.80
Rainy days	3	4	4	5	4	6	3	3	4	6	4	2

Note; Accident Frequency = $\frac{\text{Accident}}{\text{Total working hours}} \times 10^{6}$

6. Improvement in Productivity after Adoption of Protection Facilities.

6.1. Roofs .

As described above, block assembly shops arc only workshops that allow measurement of effect through the adoption of roofs. The results of survey on block assembly shops are given in the Appendix I-Collection of Data, "The results of surveys on roof installment, Table-1-4," and in Table-5, "Effects through Indoorization in major shipyards as of 1970".

Roofing a block assembly shop promises an effect of about **20 to 30%** thanks to: (1) Ability ***to*** continue work despite rain; (2) shortening of time required for arranging assembly blocks due to improved facilities; and (3) improvement in working environment due to uniformly maintained temperature.

Effect of covering is great in the northern part in winter because it can prevent reduction in efficiency arising from stopping of cranes due to strong winds, snow removing work due to low temperatures.

Covering of pre-erection shops and building docks and berths have been rarely practiced in Japan despite its great effect expected, except newly built giant shipyard like shipyard Y in western region. However, we can not obtain any stable data there at present, because the operation has just begun there in 1972.

6.2. Protection Tools and Facilities

As a direct method protection tools are supplied to cope with bad working environment. According to the results of the questionnaire, this, coupled with improvement in moral of workers, has an effect of about 5% for equipment standards in Table 6 to 9 in Collection of Data.
The estimation of 58 increase in efficiency is based upon

the opinions of experts questioned, for it is further difficult to single out the effect of the adoption of particular protecion tool, say cool suits or portable body warmer on the productivity. These tools, it seems, have a more direct effect upon the motivation to work as whole.

6.3. Crane Clamping Devices

A Japanese crane construction standard provides that devices to prevent a crane from speeding and overturning be installed to the crane. It is impossible to calculate the effect on protection units.

6.4 Additional Works Arising from Unfavorable Working Environment and Resultant Reduction in Efficiency

Additional works required in Japan are the following direct and indirect types:

(1) Wind : e.g., crane clamping

(2) Rain : e.g., rain protection (temporary awning installation), drying, draining

(3) Snow : e.g., snow removing

(4) Heat : e.g., net and cooler installion

(5) Cold : e.g., heating

Among these works, heating is measurable. This heating work attendant on welding invloves the heating of portions of high tension steel plate and sheet to be welded with a gas burner, etc. to compensate poor welding conditions at low temperature. According to Table "Results of Survey on Additional Works" in Collection of Data compiling the results of the survey, these heating works reduce efficiency by about 20 % with ordinary welding speed taken as 100 %. The term "heating work" used here does not mean removal of moisture on nor drying a portion to be welded but raising low steel plate temperature to that optimum for welding, that is 300°-400°F.

Water removal cost in the case of heavy rain can not be extimated seperately.

Table 6-1.. Additional Work for welding in low temperature

	Heating Method	Investment	Decrease of productivity measured by man-hours (%)
Shipyard X	In welding works on docks and building berths, worker heat welding points at first through gas-burner heater & then weld immediately.	$ 380 / 5 heaters	20% reduction compared to normal weldig work
Workshop Z	Gas-burner method	$ 38 / heater	20%
Shipyard V	During winter (from November to March) no welding-work in the night (6.00p.m.-8.00p.m.). In the winter day time, stop welding works, if temperature is getting low under 23° F Using gas-burner heater	n.a.	approximate: 20%

7. Examples of Productivity Increase through Adoption of Roofs.

7.1 On the Job Compositions in the Workshop affected by Weather Protection Devices

The organization of production in the Japanese shipyards has been changed drastically, in recent years, due to the adoption of flow production system. In previous days, workers were allocated and organized by their trades to each workshop. However it became difficult to control workers on production flow and keep good efficiency by such **a** production organization based on trades. Today, in the most large shipyard in Japan, the production arc reorganized on the stage unit through construction processes and workers who belong to different trades arc mixed up in to a working unit. In the case of Shipyard W in Central region, the composition of trades (jobs) in each production stage is shown in Table 7-1.

Table 7-1 The Composition of Jobs at Shipyard W. (1)

Trades \ stage	Fabrication	Block Assembly	pre-Errection (4)	Errection (on Dock and Building Berth)
Marking	X	x	x	
Fabrication (2)	X	x	x	x
Crane Operation and Rigging	X	X	X	X
Welding	X	X	X	X
Assembling(3)	X	X	X	X
Bending and Caulking				X
Fitting (3)				X
Scaffolding				X
Launching and Testing				X

notes: (1) X denotes major trades in each stage and x denotes minor trades in it.

(2) Fabrication includes gas-cutting, bending and scale removing.

(3) including gas cutting, scale removing.

(4) Pre-Erection. In this stage, which is between Block Assembly and Errection in some shipyard, a larger Block is assembled by uniting two or more small blocks into one. The aim of Pre-Errection stage is to complement the limit of indoorized Block Assembly workshop where larger Blocks can not be assembled due to relatively narrow working surface.

In the Shipyard X there are three major section in the Hull Construction Department, i. e. Hull Fabrication, Block Assembly and Erection (including Pre-Erection stage), and three in the Outfitting Department (Table 7-2). Necessary jobs for Hull Construction Dept. are fifteen, of which welding and maintenance jobs appears in every section, hull assembly, crane operation and rigging, pneumatic service and power jobs appears in two sections. Further the workers who belong to the same job do not make one group in the Section but scattered among working groups. Hull Fabrication Section consists of about 450 workers, which are divided into three Sub-Section (Kakari). One Sub-Section, then, consists of ten Group (Han). Each Group, the smallest working unit, has a forman and fifteen ***to*** twenty workers. These working unit themselves, consist of several crafts, i. e. welders, gas cutters, platers, riggers and pneumatic serviceman etc.

Such a mixed composition of multiple jobs in the working organization, will be one of the remarkable chracteristics of Japanese shipyard. All necessary informations to control production processes are based on these mixed working organizations and not on jobs.

Table 7-2 Composition of major job by working section at Shipyard X as of 1972

Department / Section / Job	Hull Construc-tion			Out fitting		
	1	2	3	4	5	6
Hull Fabrication	x					
Hull Assembly	x	x				
Plater			x			
Welding	x	x	x		x	
Crane Operating & Rigging		x	x	x		
Pneumatic Service		x	x			
Power	x		x			
Maintenance	x	x	x	x	x	
Slipway Service			x			
Inner Fitting				x		
Interior Fitting for Living-Quarter					x	
Outer Fitting						x
Painting						x

Note: Section 1: Hull Fabrication
" 2: Block Assembly
" 3: Erection
" 4: Inner Fitting
" 5: Super Structure
" 6: Hold

Further, there is a trend to multiple workmanship in the smallest working unit.

Every worker has been trained in and has, at least, one qualified skill necessary for shipbuilding works. However, in recent years, there is a remarkable trend to have multiple skills or qualifications among worker. For example, welders in Hull Construction Department usually have other related skill, i. e. qualification as plater. Platers, in turn, can have gas cutters skill.

7.2 Available Measures on Efficiency for This Study

The measures on efficiency that are used as produce tion management indexes, daily or monthly, in each Department, depend naturally on the type of working organizations.

In the shipyard surveyed, man-hours per ton of constructed ship and/or volume of steels fabricated per month are used as measure on efficiency.

Data that show differences of efficiencies by trades do not exist, because of multi-trades working unit already mentioned.

Any physical measure like welding lengths per man per shift can not be obtained unless one carry out special observation beside the production line. It is impossible for us to do such special observations within limited term and thus we have to relied upon available existing informations on efficiencies.

7.3 Example A.

We have obtained during our survey man-hours statistics at particular workshop, i.e. Block Assembly Shop at Shipyard X. In this shop the surface was uncovered in 1968, where roofs were installed in 1970. We calculated the productivity increase using these man-hours data as a clue.

Table 7-3 ..Areas covered under roof (1970)

Block Assembly shop	(1) Total Area sq. ft.	(2) Covered sq. ft.	(3) Covered ratio. (2)/(1)x100
A	41,980	26,910	64%
B	11,840	7,104	60%
C	16,146	10,226	63%
Total	69,966	44,240	63%

Table 7-4 Productivity measures recorded, in 1968, in the term of man-hours per square meteres of Block Assembly shops listed bellow.

Block Assembly shop	man-hours consumed on the area (H/Y)	← of which → welding man-hours	%	number of workers in average (man)
A	136,800	84,820	62	50
B	86,400	47,520	55	30
C	172,800	96,770	56	70
Total	396,000	229,110	58	150

note: These man-hours were consumed on the uncovered area in 1968 where roofs were installed in 1970. Therefore, 396,000 hours are corresponding to the covered 44,240 ft^2 in 1970 in Block Assembly Shops A.B.C.

Table 7-5 . , Working hours affected by rains, in 1968, before the installation of roofs.

	days or hours affected per worker	total loss time (hours)	remarks
1) Fully idle days	22 days	42,420	The days, precipitation is over 0.004 inch/H at 08:30 a.m. and all workers are ordered to back home.
2) Interruption of welding works only	86 hours	12,242	The days, precipitation became over 0.004 inch/H after beginning of operation.
3) Interrution of all works	88 hours	12,242	The days, precipitation became over 0.004 inch/H after beginning of operation.
4) Reduction of efficiencies due to the drizzling rains and interruption listed above in related works	50 hours	9,356	In drizzling rains, that are under 0.004 inch/H, all works can be continued. However there occur efficiency reduction in some degree.
Total	——	64,018	——

In 1970, the uncovered area above mentioned in this Block Assembly Shop was covered by roofs and thus they could eliminate the loss times due ***to* the** rain that amounted to 64,018 hours in 1968. The loss rate of working hours in 1968 can be obtained by a ratio of total loss times to total man-hours at that year on the particular area in Block Assembly Shop. This was 16% annually, i.e.

$$\text{loss time ratio} = \frac{\text{Total loss times}}{\text{Total man-hours}} \times 100\%$$

$$\frac{64{,}018}{396{,}000} \quad x = 16.2\%$$

We can read approximately this loss time ratio as productivity increase ratio by the adoption of roofs over ***these*** particular area of Block Assembly Shop. It is because that when roofs were installed over the area, the production methods there were changed drastically. The most significant change must be taken place in the type of cranes, i.e. from jib type to overhead travelling one and consequently in their handling and lifting capacities. This leads to other changes in supplying and handling procedures of sheets and pieces on the production lines, in distribution and location of tools, e.g. those for cutting and welding and total number of workers on the area. Therefore even if we obtain the productivity figures for 1970 at the same workshop, we should not compare this figure with those of 1968 to estimate the effects due to the installation of roofs. The above estimated gains of 16.2% can be considered as the most conservatively calculated figure based on the conditions that there is no change except roofs in the production methods.

7- 4. Example B.

As we already described in Section 2.3, the "indoorization" process had begun in some Japanese Shipyard as early as on later half of 1950's. At that time, the engineers in Shipyard IV estimated the productivity gains if they installed roofs over Block Assembly Shop. The basis of estimation and the result are as follows. The estimation had been made on the data of seven months from April to October 1957. The estimation was based on the production volume per hours and production reduction due to rain was calculated 23.6% (Wr/Wf x 100).

In this case the differences of man-hours consumed due to the different size and type of ships were assumed to have no significant effect upon production volume. It was assumed, too, the necessary man-powers were always supplied to the workshop to keep the marginal production capacities.

The introduction of roof over this workshop eliminated the reduction of production due to rain. However we have to add further gains, i.e. reduction of piece stock for rain and changes in crane capacity and production methods.

This old estimation can be used as standard and classical calculation on the effect of rains.

Basis of estimation

(A) Reduction of Prodction due to rain

$Wr = K \times R$

here $K = \frac{W}{H-(R+E)}$

Wr=Reduction of Production due to rain
R=Loss time due to rain
W=Production Volume
K=Production Volume per hour in net working hours
H=Total working hours
E=Loss time due to labour dispute

H is defined as

$H = Hw - Hh + \eta H'h$

here Hw=Total workinng days x normal working hour per day
Hh=Total holidays x normal working hour per day
$H'h$=Total working days in holiday x normal working hour per day
η= Operation ratio in holiday

$= \frac{m}{H''} \cdot \frac{1}{M}$

here m=Total workers who work in holiday
M=Average of workers in weekday
H''=Total working days in holiday

R is defined as

$R = Rw - Rh + \eta R'h$

here Rw=Total rainy hours in normal working hours
Rh=Total rainy hours in holiday
$R'h$=Total rainy hours in working hours in holiday

E is defined as

$E = Ed + Ei$

here Ed=Direct loss time due to labour dispute
Ei=Indirect loss time due to labour dispute

(B) Reduction of Production due to labour dispute (We)

$We = K \times E$

(C) Operation capacity of Block Assembly Shop (Wf)

Wf=W+Wr+We

here wf is defined as normal production volume on Block Assembly Shop if there occur no rainy days and Iabour disputes

(D) Normal working hours was nine hours per day,

i.e. 8.00am-noon, 1.00pm-6.OOpm.

Table 7-6 Effects of rains to Block Assembly Shop

Observed at Shipyard N during 7 months
(April to October) 1957.

Item / month	Total working hours (h)	loss time due to rains (h) (R)	loss time due to labor dispute (h) (E)	Volume of production per month (tons) (N)	Volume of production per hour (t)	Losses due to rains (t) (Nr)	Losses due to labor dispute (t)	Full capacity when Nr=0 Ne=0 (t) (W)
April	243.0	53.5	0	5641	29.7	1590	0	7231
May	248.4	69.0	0	5427	30.2	2080	0	7507
June	235.8	62.2	0	5056	29.1	1805	0	6861
July	239.0	73.9	38.5	3662	28.9	2140	1115.0	6917
August	243.4	21.0	0	6042	27.2	572	0	6614
September	241.6	96.5	0	4074	28.2	2720	0	6794
October	249.9	25.3	14	6118	29.2	740	406.0	6853
Average	243.0	57.3	7.5	5145.7	28.9	1655.0	217.0	7017.7

8. Weather Protection Devices ,in the Heavy Equipment Industries.

8-1. Description of Workshop Z

As wc have already described in our Research Proposal, we restrict the scope of heavy-equipment and construction industries to be studied to the works which are carried out within the same enterprises with shipyards as a field of their diversified operation.

We have selected a large scale construction shop, workshop Z, that is located beside shipyard W in central region of Japan. Weather variations in Workshop Z is the same with that of shipyard W. (cf. 3. seq.)
The products in this workshop Z are steel bridge, highway structure, water sluice gate, hydraulic pipe, parking facilities and steel frame for building etc.

8-2. Weather protection devices adopted.

The surface of this workshop Z is not covered by roofs, exports a part of paint shop, that has a floor space of 30,030 ft^2 of which 3,305 ft^2,i.e. 11% of space is now covered by roof (the data of which are given in Table 4, Collection of Data.) Protection devices adopted other than roof are 1) heater, 2) Sunnet, 3) Water cooler and 4) Winter Cloth.
heating devices that were introduced since 1968, were small portable gas-stoves to heat workers in the closed section of steel structure on the ground (cf. Table-7, Collection of Data and photograph No. 15). Sunnet were used since 1957 to shade workers from direct sunshine during summer. At present nets are made of nylon and have different size according to the places to be used. Water cooler that is shown in photograph No.17, commercially available ordinary one to serve workers on work surface in summer. Winter cloth (photograph 18) arc supplied for rent, without fee, for every workers

during winter. The cranes on this work surface have same clamping devices as those of shipyards and the types and costs are shown in the Table-11 and 12, Collection of Data.

8.3. Their effects on productivity..

The use of protection devices are limitted to rather simple ones like portable stoves, water-coolers and winter cloth. Thus, their effects on productivity can not be singled out and, it seems, have good effect on the moral of workers in some degree.

In this workshop, preheating of welding points are usually done by gas-burner method in low temperature. These additional works for welding usually reduce the productivity measured by man-hours by about 20%. (cf. Table. 6-1. in the Report).

9 The distribution of shipbuilding costs in Japan

9-1 The method of estimation

The shipbuilding cost usually differ from the type and size of ship and from the conditions on which shipyard operates. Although tankers are the largest single type of ships that are constructed in Japan, there are wide variety of ships constructed among 25 major shipyards here, and it is impossible to get average figures on the shipbuilding costs. Another difficulty arises from the fact that the field of business of the most shipbuilding enterprises? have been diversified significantly in recent years, and it distort cost figures appeared in company's annual financial statements.

Consequently, we select two shipbuilding companies whose manufacturing activities concentrate on shipbuilding and especially on single type of ship, so as to get relatively stable and reliable cost pictures. The figures base on the financial statement of these companies.

9-2. The distribution of shipbuilding costs

The shipbuilding company A has only a large shipyard in western region, according to climate classification used in this report, and the sales of shipbuilding department accounts for 82% of the annual company sales in 1971. The three fourth of shipbuilding sales comes from new construction and one fourth comes from reparting. The main product here is large tanker of 200,000 dwt.

The shipbuilding company B has also one major shipyard in northern region and the share of shipbuilding accounts for 88% of total annual sales in 1971. New construction was 94% of total shipbuilding sales in this year. The main

product in this company is small bulk-carriers from 25,000 tons to 28,000 tons in deadweight.

As for the cost items, Raw Material is including subcontractors and purchasing, Overhead is including the cost for capital components and salaries in general and administrative departments.

The distribution of costs in 1971 are shown in the Table 7-1, Raw Materials item accounts for about the half and Labour cost for slightly under 20%, whereas the Overhead is over 30%.

Table 9-1. The Distribution of Shipbuilding Costs compared with other Manufacturing Industries in Japan. 1971 (%)

Cost items / Shipyards and Industries	Raw Materials	Labours	Overhead charges	Total
Shipbuilding Co. A	49.1	19.8	30.9	100.0
Shipbuilding Co. B	50.4	15.8	33.6	100.0
Machinery Industry (except electrical)	60.3	16.9	22.8	100.0
Electrical Machinery for Industrial Use	51.8	21.1	27.1	100.0
Railway locomotives	60.3	16.9	22.8	100.0

SOURCE : Mitsubishi Research Institute, Kigyo keiei no Bunseki (Financial Analysis of Japanese Corporations), No. 38, Dee, 1972.

Appendix H-1

Collection of Data

Appendix H-1.

Collection of Data

Explanatory Note to Table of Protection Facilities

(1) The results of survey on rool installment

Table-l. Work environment with roofs
Type of workshop: No.1.

Table-2 do: No.2.

Table-3 do: No.3

Table-4 do: No.4

(2) Table-5 Effects through "Indoorization" in *major* shipyards as of 1970.

(3) The results of survey on protection facilities and devices

Table-6 Work environment-heat and cold protection facilities, Type of workshop: No.1.

Table-7 do: No.2

Table-8 do: NO.3

Tab2e-9 do: No.4

(4) The results of survey on czane protection

Table-10 Protective equipment exclusively for cranes,
Type of crane No.2

Table-11 do: No.3

Table-12 do: No.4

Explanatory Note to Table of Protection facilities

Items	Definitions	Remarks
1. Type of Workshop	1. Block Assembly 2. Pre-Erection (Grand Assembly) 3. Erection 4. Coating	on dock or building berth
2. Type of Roof	1. Permanent building, wholly closed 2. " , with travelling roof 3. Permanent building with roof, not wholly closed. 4. Travelling roof	
3. Covered Area	1. Covered ratio of Block Assembling Shop= $\frac{\text{Square meter of indoorized assembling surface}}{\text{Square meter of total of assembling surface}} \times 100$ 2. Covered ratio of Pre-Erection Shop= $\frac{\text{Square meter of indoorized pre-erection surface}}{\text{Square meter of total pre-erection surface}} \times 100$ 3. Covered ratio of Building Berth and Dock= $\frac{\text{Square meter of covered area}}{\text{Square meter of Building berth and Dock}} \times 100$	
4. Type of Acquisition (Roof)	1. Owened 2. Rental	
5. Capital Costs (Roof)	Building Construction Cost+ Civil Engineering Cost and Cost for Auxiliary Facilities	

Explanatory Note (continued)

Items	Definitions	Remarks
6. Operating Cost	Yearly maintenance cost for particular covered area	
7. Type of Protection Devices.	1. Ventilating Fan. 2. Air Conditioner & Stoves 3. Water Cooler 4. Winter Cloth 5. Sunnet 6. Cool Suits.	
8. Type of Utili-zation	1. Supplied as standard equipment to workers 2. Lended when need arises	
9. Capital Cost (Devices)	Costs to introduce or purchase the devices	
10. Operating (Devices)	Yearly replacement costs	
11. Type of cranes	1. Overhead traveling crane 2. Bridge crane 3. Jib crane 4. Goliath crane	
12. Crane capacity	Lifting capacity	
13. Type of workshop	same as Item 1.	
14. Type of protection methods.	1. Rail clamping 2. Hooking 3. Pin drop 4. Guy wire	
Operating costs	Yearly main-tenance costs for particular protection method	

(1) The results of enquête on roof installment

Table 1. Work environment with roofs

Type of workshop: No.1

Shipyard	Floor space of work shop, ft^2	Covered space ft^2	Covered rate (%)	Type of covering	Type of acquisition	Capital costs \$ per ft^2	Operating costs \$ per/year	Description of facilities: Code number of photos	Description of facilities: specification of structures
W	39,611	35,305	89	1		-		1.2.	steel structure, galvanised iron sheet
X	85,357 143,697	85,357 143,697	100 100	1 1+3		14.55 14.12	6,004 10,260	1.2. 1.2.3.	", " ", "
Y	775,600	775,600	100	1		11.72		1.2	steel structure, colored iron sheet
W	27,986	27,986	100	2		15.88		4.5.6.	steel structure, long colored iron sheet
V	25,833	25,833	100	2	1	14.12		4.5.6.	steel structure, slated roof,
X	37,027	37,027	100	2		8.82	2,622	4.5.6.	steel structure, galva ized iron sheet
Y	62,107	62,107	100	2		15.42		4.5.6.	steel structure, colored iron sheet
W	91,008	59,944	66	4		3.53		7.8.	Eslon(Corrugated vinylchloride resi. sheet)
V	62,377	12,378	20	4		12.36		7.8.	steel structure, galvanized iron sheet,
X	52,635	20,666	40	4		2.12	1,444	7.8	steel structure, galvanized iron sheet,
Y	-	-	-	-					readily movable bonnet roof
total	1,403,238	1,285,905	92	The rise in productivity by covering in the cases amounts to 20 to 30 percent.					

table 2. Work environment with roofs
Type of wrokshop: No.2

Shipyard	Floor space of workshop ft^2	Covered space ft^2	Covered rate (%)	Type of covering	Type of acquisition	Capital costs $/$ft^2$	Operating costs $ per year	Description of facilities	
								Code number of photos	specification of structure
Y	447,508	97,682	21	2	1	15.42	-	4.5.6.	steel structure, colored iron sheet
total	447,508	9,075	21						

table 3. Work environment with roofs
Thpe of wrokshop: No. 3

Shipyard	Floor space of workshop ft^2	Covered space ft^2	Covered rate (%)	Type of covering	Type of acquisition	Capitalcosts $/ft2	Operating costs	Description of facilities	
							$ per year	Code number of photos	specification of structure
Y.	1,130,206	107,640	10	4	1	25.60	-	7.8	steel structure, colored iron sheet
total	1,113,206	107,640	10						

H-70

table 4. Work environment with roofs
Thpa of wrokshop: No.4

Shipyard	Floor space of workshop ft²	Covered space ft²	Covered rate (%)	Type of covering	Type of acquisition	Capital costs $/ft²	Operating costs $ per year	Description of facilities: Code number of photos	Description of facilities: specification of structure
Y	80, 730	80,730	100	1		9.00		4.5.6.	steel structure, colored iron sheet
X	35,520	35,520	100	2	1	15.88	2,508	9. 10	steel structure, galvarized iron sheet
Z	30,000	3,300	11	2		30.18	1,140	9. 10	" "
W	30,250	21,530	71	4		8.93	-	11. 12	"
total	176,500	141,080	80						

(2) Table 5.

Effects through "Indoorization" in major shipyards as of 1970.

Region	Shipyard	Increase of floor use rate (%) (1)	Reduction of manhours (%) (2)	Remarks
Northern	V	40	20	
	E	10-15	5 (only for outdoor works)	
Central	W	30	15	
	L	20-25	15	
	K	20	15	
	J	in somedegree	10	plus improvement in working environment
Western	O	20	15	increase in safety and quality through improvement in working conditions.
	P	100 (in final assembling)	30	
	X	10	10	

Note: (1) ratio of fabricated steel in tons persquare meters of assembling yards. This ratio does not directly correspond to the annual increase rate of production capacity. By increasing floor use rate at particular workshop, additional works could be done, if other poduction factors, especially manpowers, were provided to carry out this additional works. Empirically, annual increase of production capacity rather corresponds to the rate of reduction of man-hour consumed.

(2) man-hours per tons of ships constructed.

Source: Nihon Zosen Kogyokai (Shipbuilders' Association of Japan)

(5) The results of survey on protection facilities and devices

Table 6. Work environment-heat and cold protection facilities

Type of workshop: No. 1

Workshop	Type of protection facilities	Standard of equipment (number of units per person)	Type of acquisition	Capital Costs: number of facilities (number of unit per person)	Capital Costs: cost per unit ($/unit)	Capital Costs: total cost ($)	Operation Costs: number of supplemented facilities (number of units per person)	Operation Costs: cost per unit ($)	Operation Costs: cost per unit ($/person/year)	Specification: Code number of photos	remarks
X	1	0.25		0.248	357.2	62151.2	0.026	357.2	9.11	13.14	
Y		0.20	1	0.195	407.0	62320.0	-	-	-	13.14	
W		0.42	2	0.420	357.2	46793.2	0.176	38.0	6.70	13.14	
W	2	0.02		0.022	60.8	433.2	0.022	11.4	0.25	15	
V	2	0.20	1	0.198	60.8	2158.4	-	-	-	15	
X		0.04		0.036	190	3990.0	0.003	190.0	0.65	17	
Y	3	0.03	1	0.027	247	5187.0	-	-	-	17	
W		0.03		0.048	190	2850.0	0.048	19.0	0.91	17	
V		0.08		0,008	171	342	-	-	-	17	
Y		0.01		0.013	13.3	133.0	-	-	-	16	
W	4	0	1	0	-	-	-	-	-	18	
V		1.00		1.000	190	2660.0	-	-	-	18	
X	5	0.02	1	0.017	15.96	159.6	0.002	15.96	0.027	-	
W		0.03		0.032	15.96	159.6	-	-	-	-	
X		0.14	1	0.136	38	3040.0	0.014	38.0	0.52	19	
Y	6	0.08	2	0.077	30.4	1824.0	-	-	-	19	
W		0	1	0	-	-	-	-	-	19	

(3) The results of survey on protection facilities and devices

Table 7. Work environment-heat and cold protection facilities

Type of workshop: No.2

Workshop	Type of protection facilities	Standard of equipment (number of units per person)	Type of acquisition	Capital Costs: number of facilities (number of unit per person)	Capital Costs: cost per unit ($/unit)	Capital Costs: total cost ($)	Operation Costs: number of supplemented facilities (number of units per person)	Operation Costs: cost per unit ($/unit)	Operation Costs: cost per unit ($ / person/ year)	specification: Code number of photos	remarks
X	1	0.14	1	0.143	357.2	10716	0.014	357.2	2.33	13.14	
Y		0.19		0.194	368.6	12160	-	-	-	13.14	
Z	2	0.05	1	0.050	190.0	1140	0.042	190.0	0.95	15	
X	3	0.02	1	0.024	190.0	950	-	-	-	17	
Z		0.08		0.083	72.2	722	0.017	72.2	1.20	17	
Y	4	0.07	1	0.071	13.3	159.6	-	-	-	18	
Z		1.00	2	1.000	11.4	490.2	0.233	11.4	2.65	18	
X	5	0.04	1	0.048	15.96	159.6	0.005	15.96	.076	-	
[illegible]		0.27		0.267	15.96	509.2	0.083	15.96	1.33	-	
X	6	0.29	1	0.236	38.0	2280.0	0.029	38	1.09	19	

(3) The results of enquete on protection facilities and devices

Table 8. Work environment-heat and cold protection facilities

Type of workshop: No.3

Workshop	Type of protection facilities	Standard of equipment (number of units per person)	Type of acquisition	Capital Costs: number of facilities (number of unit per person)	Capital Costs: cost per unit ($ /unit)	Capital Costs: total cost ($)	Operation Costs: number of supplemented facilities (number of units per person)	Operation Costs: cost per unit ($ /unit)	Operation Costs: cost per unit ($ /person/year)	specification: Code number of photos	remarks
X	1	0.28	1	0.278	357.2	89300	0.028	357.2	9.94	14	
Y		0.17		0.168	541.9	109440	-	-	-	14	
W		0.30	2	0.302	357.2	57152	0.094	38	3.58	14	
V		0.31	1	0.310	342.0	40356	-	-	-	14	
X	2	0.02	1	0.016	11400.0	159600	-	-	-	16	
W	2 cooler	0.02	2	0.015	11400.0	91200	-	-	-	16	
V	2	0.05	1	0.052	38.0	760	-	-	-	15	
X	3	0.03	1	0.026	190	4370	0.002	190	0.42	17	
Y		0.02		0.023	247	6916	-	-	-	17	
W		0.03	1.2.	0.026	190	2660	0.026	19	0.50	17	
V		0.02	1	0.016	114	684	-	-	-	17	
Y	4	0.10	1	0.098	13.3	1569.4	-	-	-	18	
W		0.57		0.566	8.7	2622	-	-	-	18	
V		1.00		1.000	19	2869	-	-	-	18	
X	5	0.33	1	0.334	15.96	4788	0.033	15.96	0.53	-	
W		0.77		0.774	15.96	6543.6	-	-	-	-	
X	6	0.61		0.612	38	20900	0.061	38	2.33	19	
W		0.06	2	0.057	45.6	1369	-	-	-	19	

(3) The results of survey on protection facilities and devices

Table 9 . Work encironment-heat and cold protection facilities

Type of workshop: No.4

Workshop	Type of protection facilities	Standard of equipment (number of units per person)	Type of acquisition	Capital Costs: number of facilities (number of unit per person)	Capital Costs: cost per unit ($ /unit)	Capital Costs: total cost ($)	Operation Costs: number of supplemented facilities (number of units per person)	Operation Costs: cost per unit ($./unit)	Operation Costs: cost per unit ($ / person/ year)	specification: Code number of photos	remarks
Y	1	3.14	1	3.140	419.5	65,888.2	-	-	-	13.14	
W		0.80		0.800	950	15,200	-	-	-	13.14	
W	2	0.20	1	0.200	2,280	9,120.	-	-	-	15.	
Y	3	0.06	1	0.060	247	741.	-	-	-	17	
W		0.05		0.050	190	190	0.050	190	9.5	17	
Y	6	3.00	1	3.000	30.4	4,560	-	-	-	19	

(4) the results of survey on crane protection

Table. 10 Protective equipment exclusively for cranes

Type of crane: No.2

Workshop	Capacity of crane	Place of equip-ment	Type of protective equipment	Total of capital ($)	Operating costs ($ per year)	Protective equipment code number of photos	specification of structure
W	31T	1	1	775.2	26.6	20	steel
	40T		1.3.	615.6	26.6	20.23.24	"
	10T		3		26.6	23.24	"

(4) the results of survey on crane protection

Table 11. Protective equipment exclusively for cranes

Type of crane. No.3

Workshop	Capacity of crane	Place of equip-ment	Type of protective equipment	Total of capital ($)	Operating costs ($ per year)	Protective code number of photos	equipment specification of structure
W	80T/40T	3	1.3	2,223.4	83.6	20.23.24	steel
	40T/15T	1	1.3.4.	2,356.0	304.0	20.23.24.25	"
	20T/10T	3	1.3.4.	247.0	250.8	20.23.24.25	"
	125T/25T		1.4.	965.2	250.8	20.25	"
X	80T	1	2	7,220	-	21.22	"
	60T			5,700	-	21.22	"
W	6T/3T	3	2.4.	836	197.0	21.22.25	"
Y	100T/50T	2		9,120	494.0	23.24	"
	35T/10T	3	3	13,490	190.0	" "	"
	20T/10T	2		9,120	133	" "	"
	10T/5T	3		13,300	133.0	" "	"
W	90T/45T	3		14,440	83.6	" "	"
	80T/35T	1. 3	3	11,400	-	" "	"
	10T			2,660	-	" "	"
Z	20T/7.5T	2	3	608	60.8	" "	"
	15T/7.5T			608	60.8	" "	"
V	80T			-	-	" "	"
	50T			-	-	" "	"
	40T	3	3	-	-	" "	"
	45T			-	-	" "	"
	25T			-	-	" "	"
	10T	1		-	-	" "	"

(3) the results of survey on crane protection

Table 12: Protective equipment exclusively for cranes

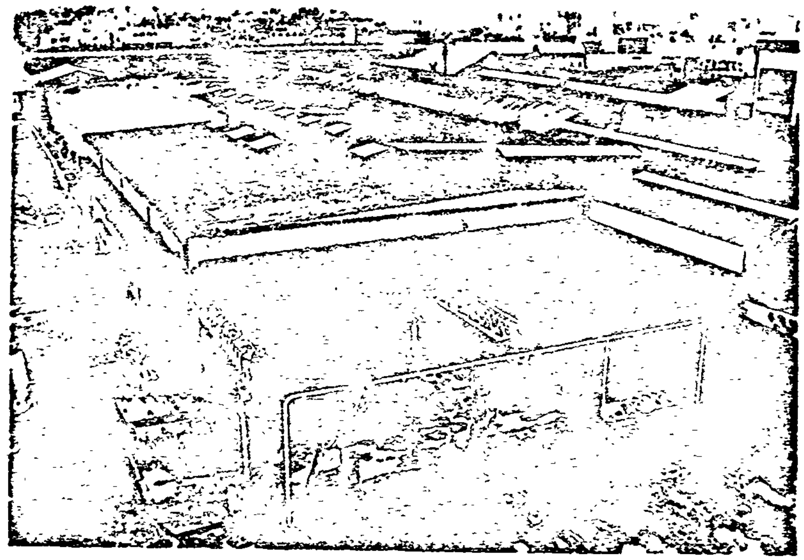
Type of crane: No.4

Workshop	Capacity of crane	Place of equip-ment	Type of protective equipment	Total of capital cost ($)	Operating costs ($ per year)	Protective equipment: code number of photos	Protective equipment: specification of structure
Y	600T	3	1.2.3.	98,800	912	20.21 22 23 24	steel
X	20T	2	2	4,180	-	21.22	"
	300T	3		23,560	-	"	"
	120T			9,652	-	"	"
	80T			8,170	-	"	"
Z	20T	2	4	1,026	49.4	25	"

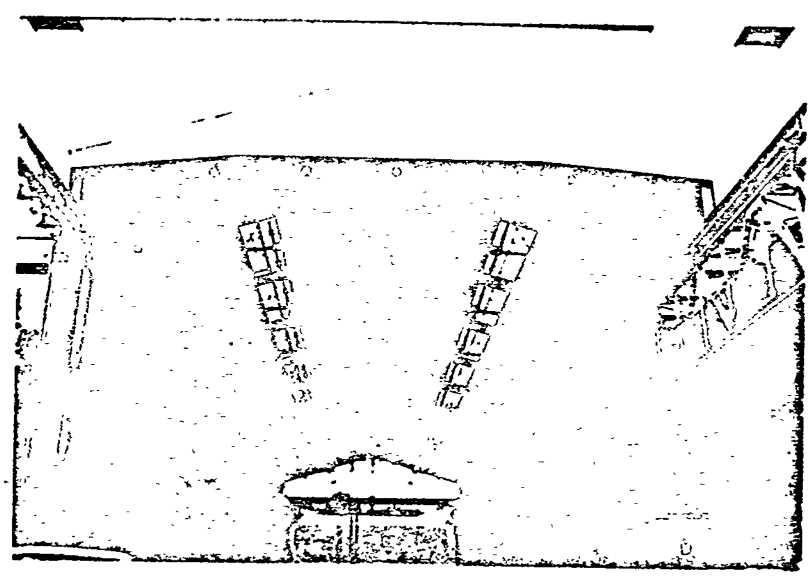
Appendix H-2

Photographed of Facilities and Devices.

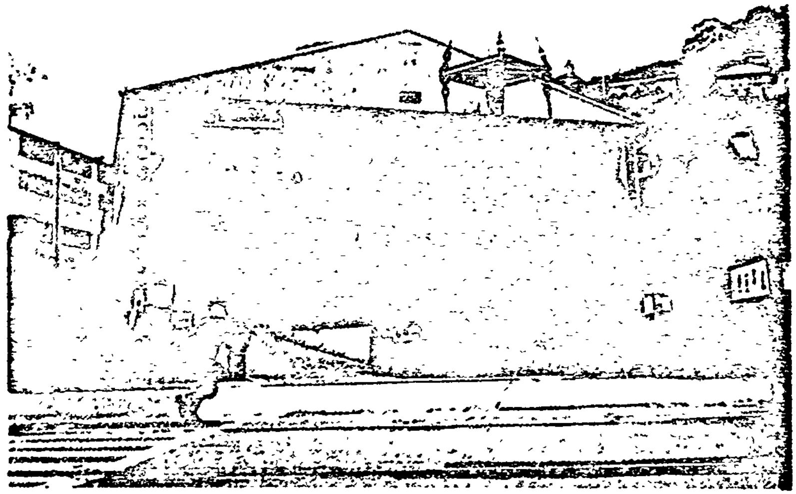
(Each number under pictures denote code number in the Tables in Appendix H-1, all pictures were taken during our survey on December and January 1973.)



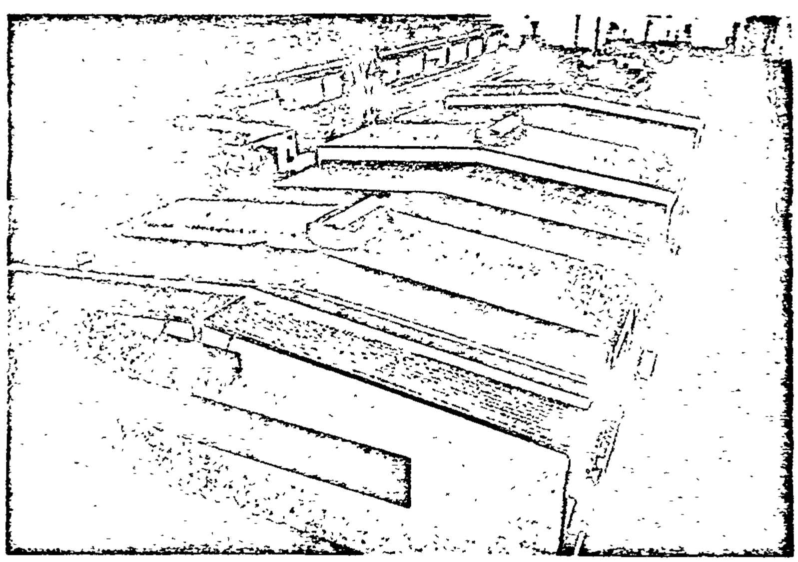
1. Roofed Block Assembly shop at Shipyard W in the Central region of Japan. Type of roof: permanent building, wholly closed.



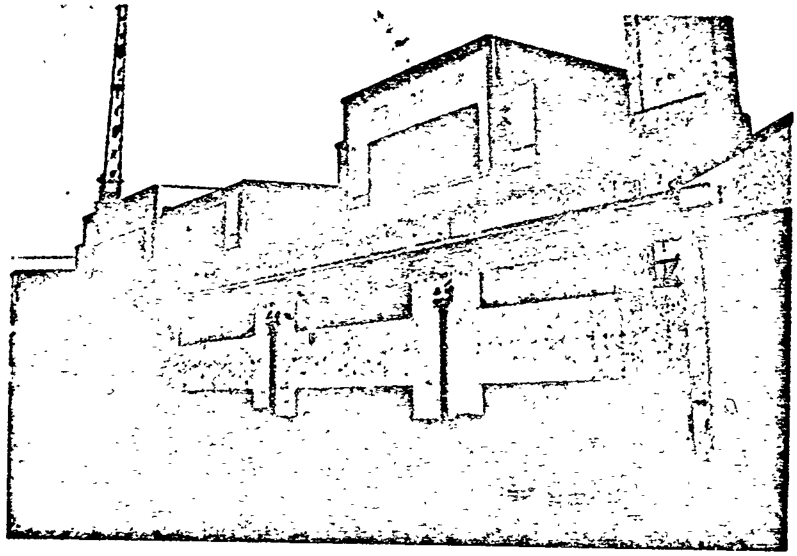
2. Roofed Block Assembly shop at Shipyard X in the Western region. Type of roof: same to 1.



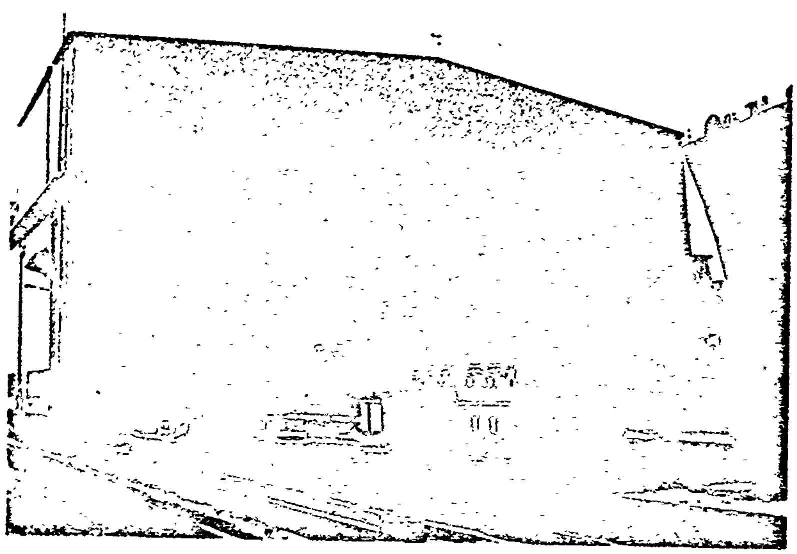
3. An assembled block is carried out from roofed Block Assembly shop at Shipyard X.



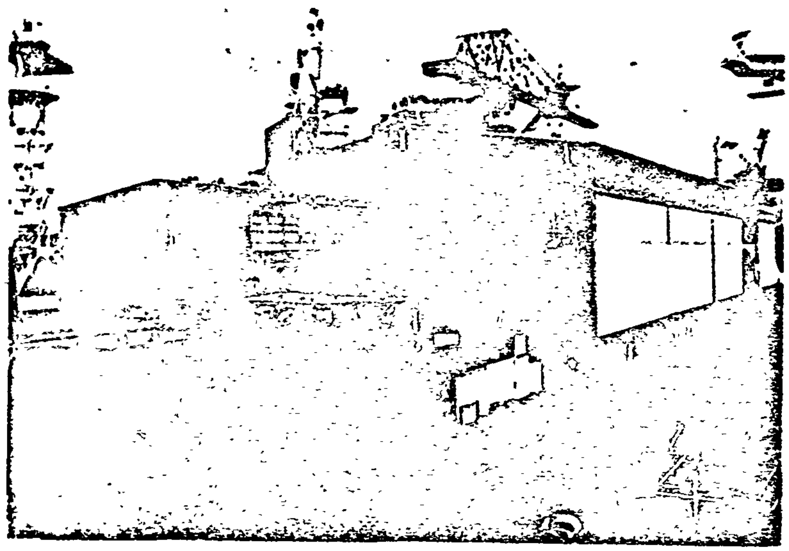
4. Block Assembly shop with travelling roof at Shipyard X. Type of roof: permanent building, wholly closed, with travelling roof.



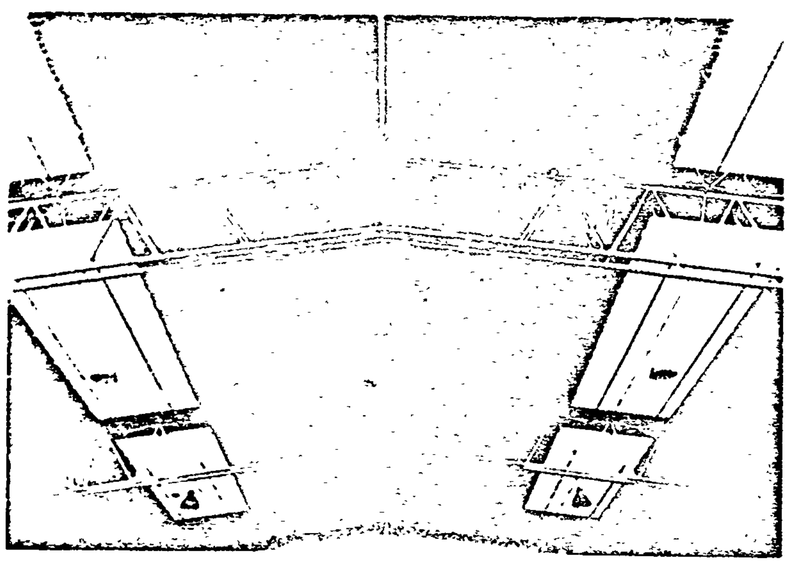
5. Block Assembly shop with travelling roof at Shipyard X. Type of roof: permanent building, wholly closed, with travelling roof.



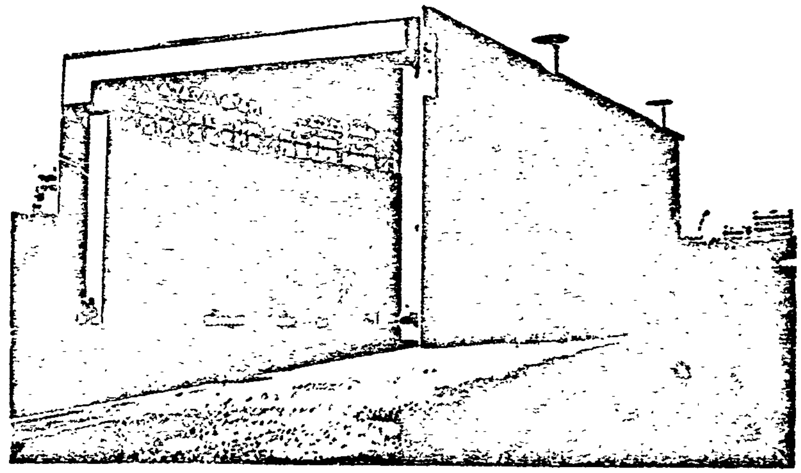
6. Block Assembly shop with travelling roof at Shipyard W.



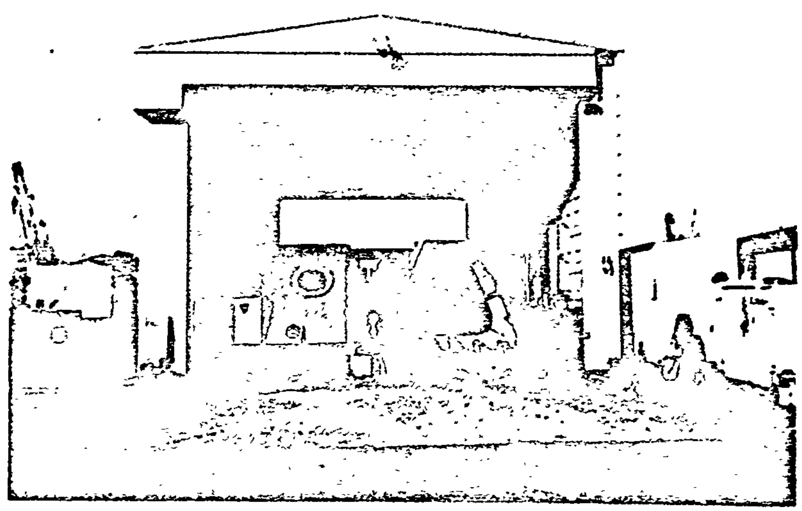
7. Block Assembly shop with travelling roof at Shipyard W. Type of roof: wholly travelling roof.



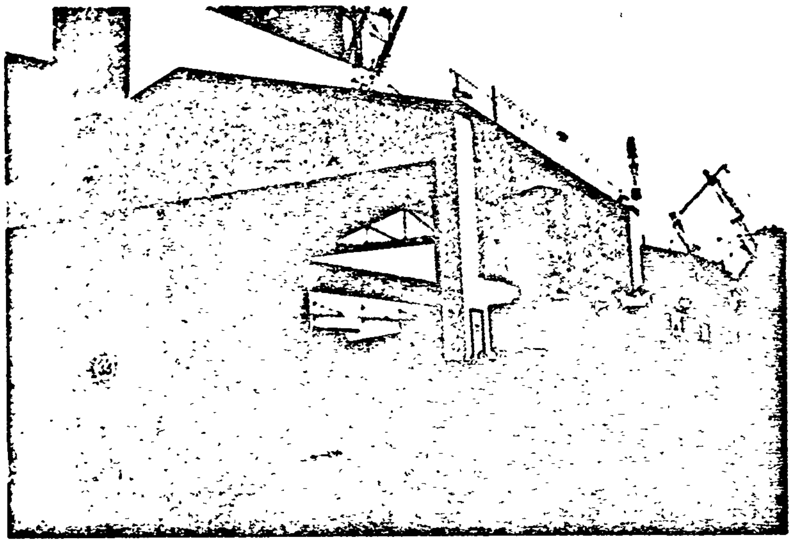
8. Block Assembly shop with travelling roof at Shipyard W. Type of roof: wholly travelling roof.



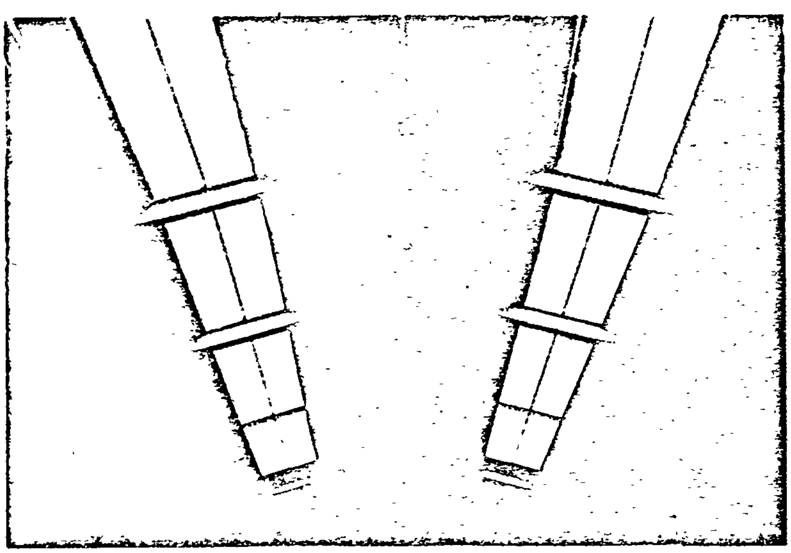
9. Painting/Coating shop at Shipyard X in the Western region.
Type of roof: permanent building, wholly closed, with travelling roof.



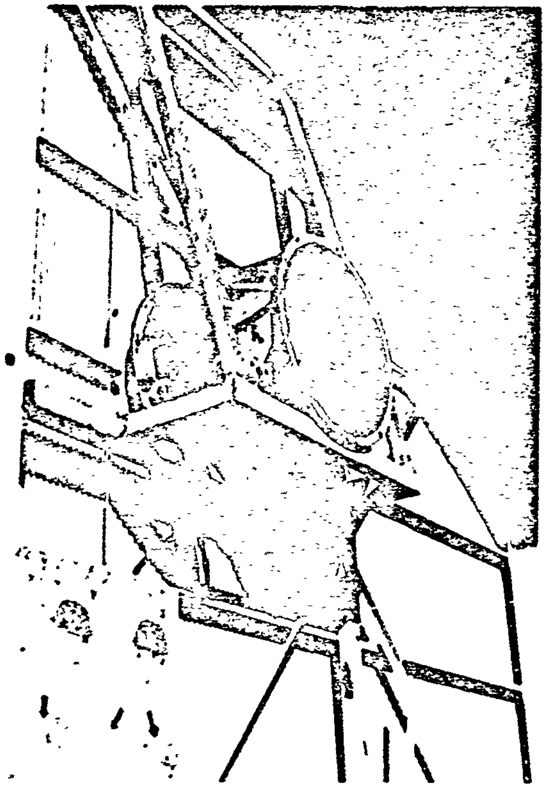
10. Painting/Coating shop at Shipyard X in the Western region.
Type of roof: permanent building, wholly closed, with travelling roof.



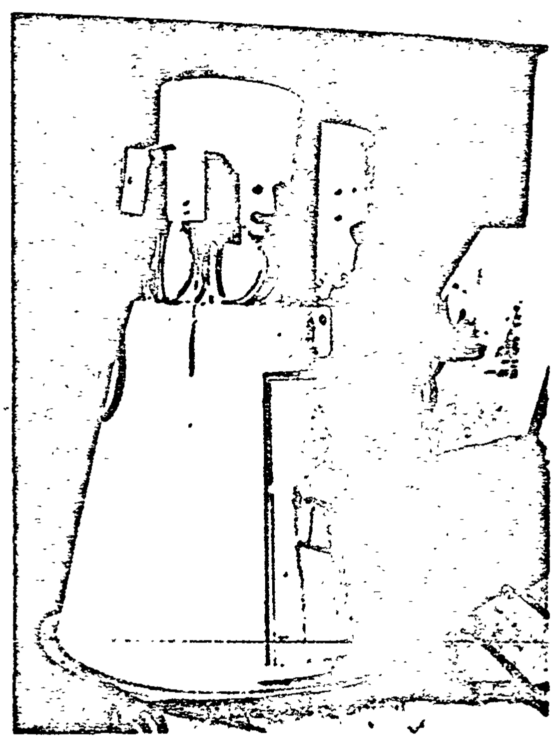
11. Painting/Coating shop at Shipyard W. Type of roof: Travelling roof.



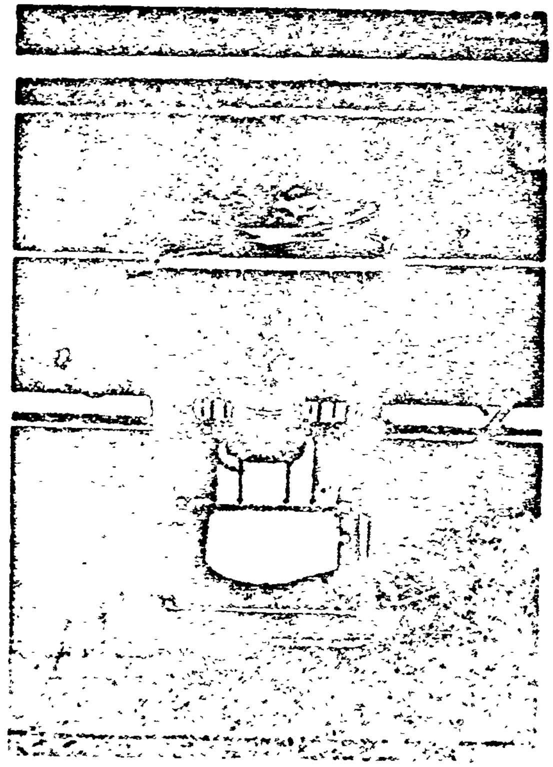
12. Painting/Coating shop at Shipyard W. Type of roof: Travelling roof.



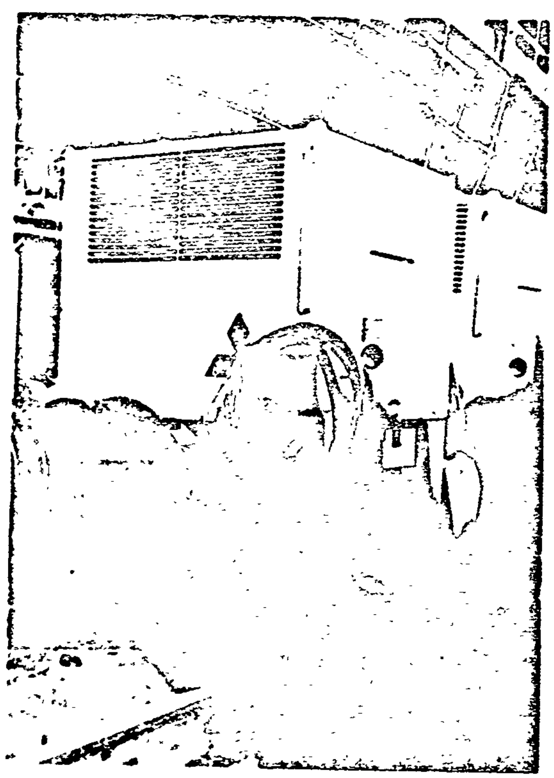
13. Ventilating Fan.



14. Ventilating Fan.



15. Gas Stove.



16. Air Conditionning Unit on the dock.

3 OF 3

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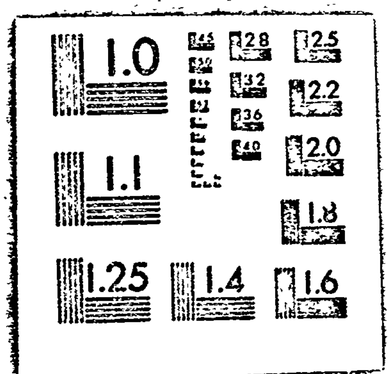
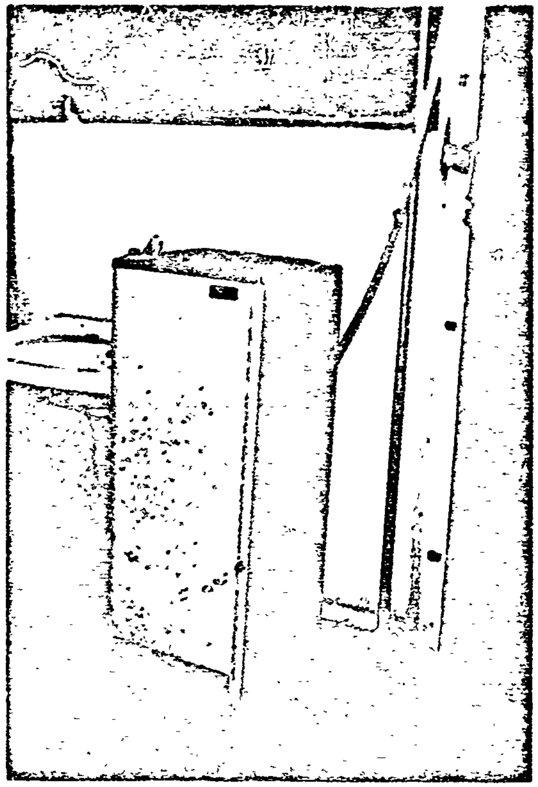
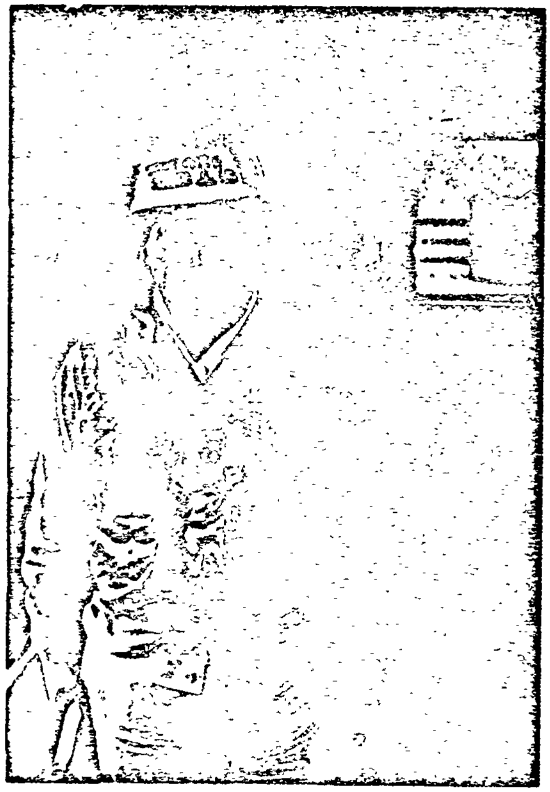


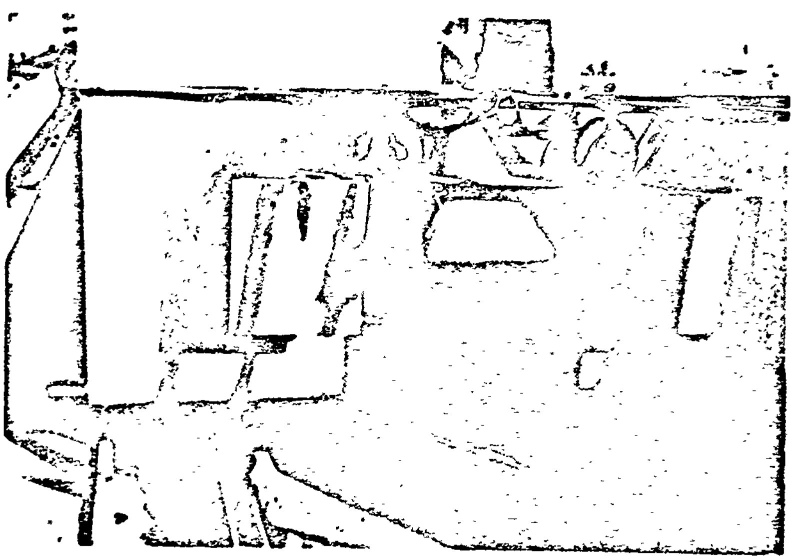


17. Water Cooler.

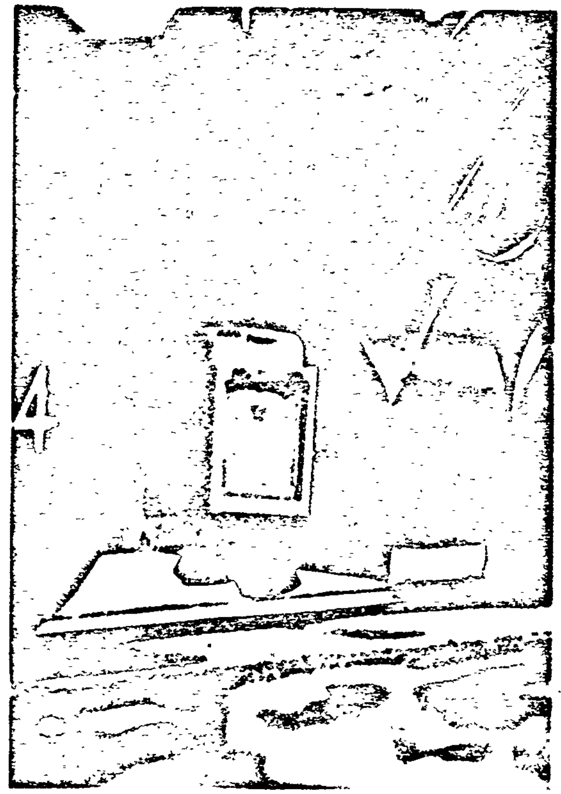
18. Winter Clo..,



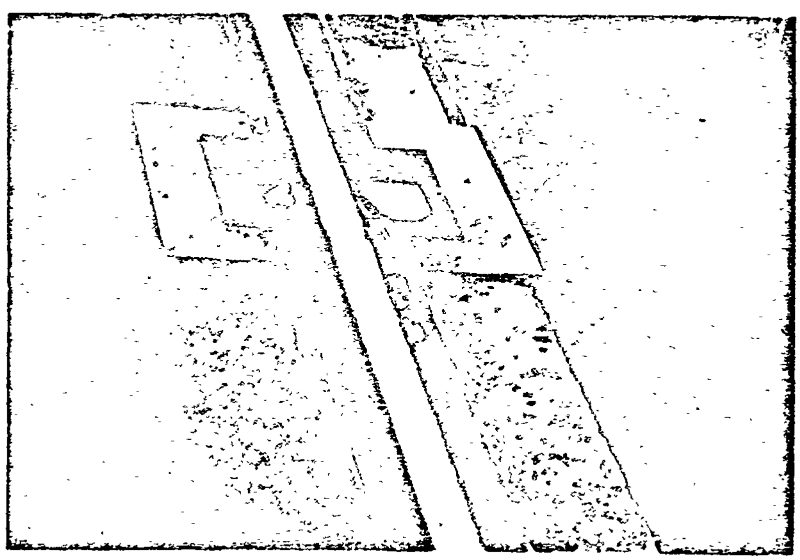
19. A foreman wearing Cool Suits.



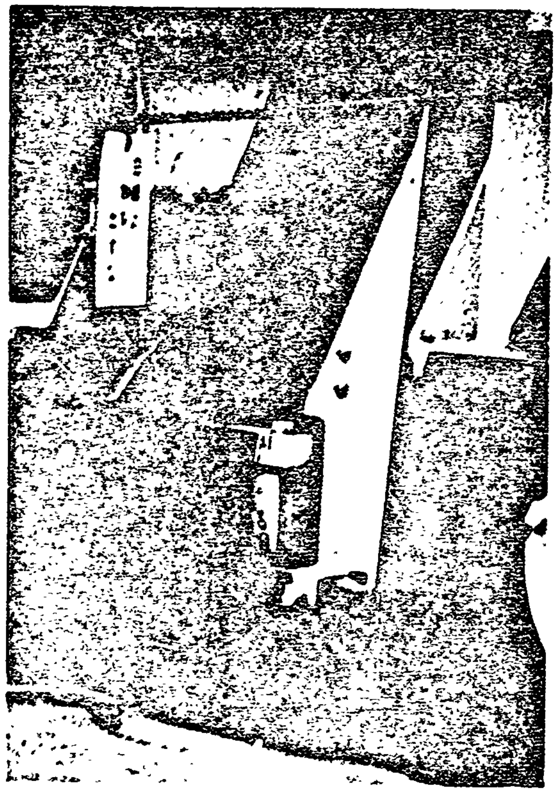
20. Rail clamping device for Bridge crane.



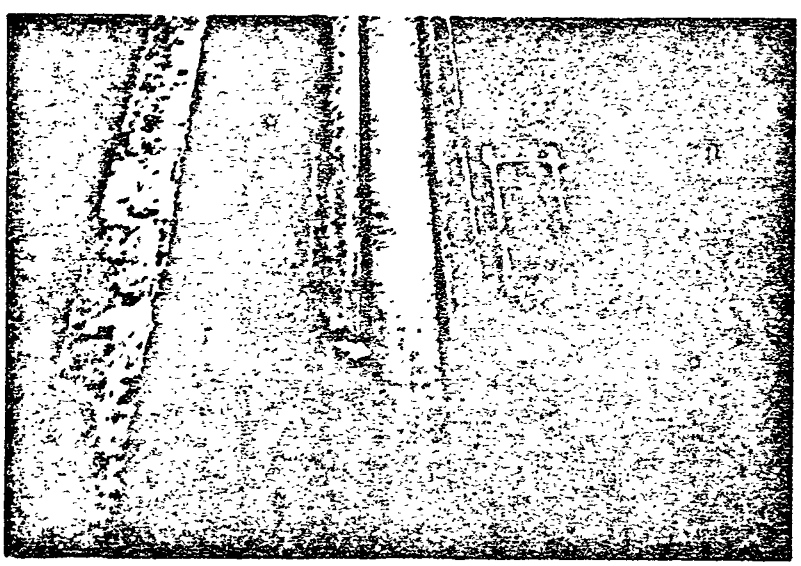
21. Hooking device for Goliath crane.



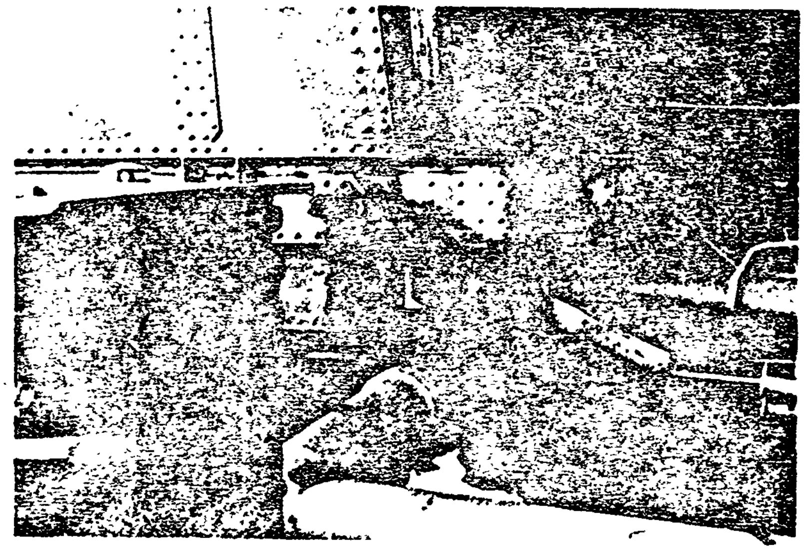
22. Hooking device for Goliath crane.



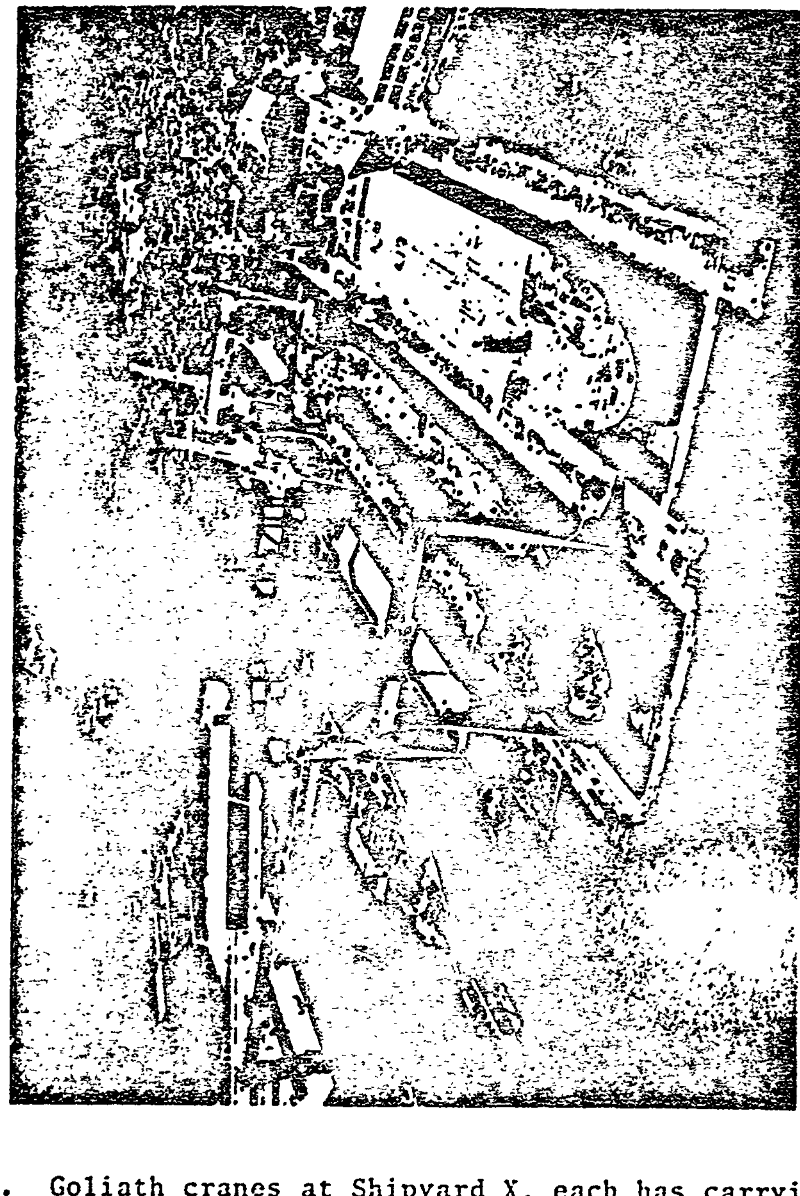
23. Pin drop device for Bridge crane.



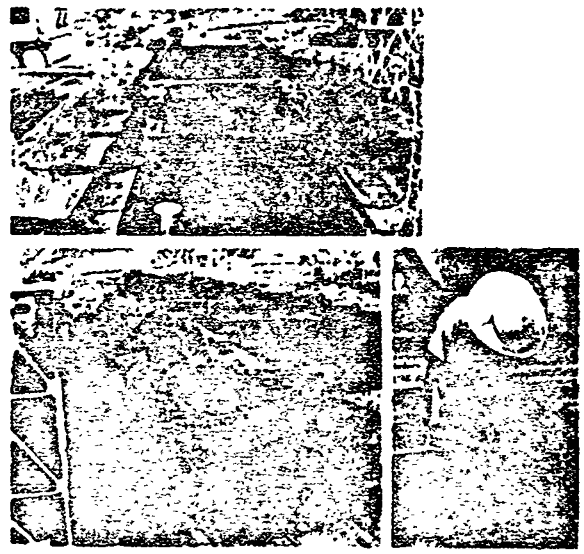
24. Pin drop device for Bridge crane.



25. Guy wire for Jib crane.



26. Goliath cranes at Shipyard X, each has carrying capacity 300 tons.



27. Sunnets over upper deck on the dock.

APPENDIX I

STATE-OF-THE-ART IN HEATHER PROTECTION FACILITIES IN THE EUROPEAN SHIPBUILDING INDUSTRY

Battelle-Frankfurt Laboratories, Frankfurt, Germany conducted a study, "Heather Protection Facilities at European Shipyard", under a subcontract to Battelle-Northwest a part of this study. That report is reproduced here.

The report includes estimates of increases of productivity and actual increases of productivity for working with weather protection facilities along with capital and operating costs of several structures.

Reference is madeon Page 12 of the report to English summaries of articles written in German. These are attached following the appendix section of the report. Photographs of movabie "halls" and a hoarding panel system used in Germany are included at the end of the report.

Weather Protection Facilities

at European Shipyards

February 1973

A. Introduction

It is the intention of this report to describe the different types of weather protection facilities used at European yards and to demonstrate the improvements in worlcimg productivity and costs.

Literature reviews could only urnish a small part of the information required for the study- S0 special questionnaires were sent out to selected European shipyards and in addition, some German shipyards were contacted by telephone.

ortuxmtely the results of these activities were not sufficient because most of the shipyards were *not* willing to cooperate-

Therefore the following information, especially the quantitative figures, can not be representative for the European shipbuilding industry.

Nevertheless, the figures delivered by questionnaires of two German, one Dutch and one Swedish shipyard, have been included in this report to give at least an order of magnitude. The report arrangement which has been proposed by BNW, has been taken over as far as possible.

B. Designs, costs and effects of weather protection facilities

1. Permanent and portable weather Protection facilities used at European shipyards

1.1 Facility designs

The following weather protection facilities of different types and dimensions and for several. shipbuilding activities are in use:

- halls with fixed roof

construction:	steel or reinforced concrete with overhead travelling cranes
used for:	marking, burnings welding. erecting of panels and sections

- halls with traversing roof

construction:	steel or reinforced concretc with overhead traveling cranes or other cranes. working from outside through the open roof

used for: marking, burning, welding, erecting of panels and sections

- movable halls

  construction: steel frame; steel- or other material-plating

  moved by: vehicle, workmen

  used for: marking, burning, welding, erecting of panels and sections, assembling

- sheds

  construction: steel

  used for: sandblasting, painting, storage, general purpose

- shacks

  construction: wood

  used for: storage, general purpose

- portable roofs

  construction: steel frame with corrugated plate

  moved by: crane

  used for: marking, burning, welding, painting

- tarpaulin shelters, tents

  used for: burning, welding, painting, storage, general purpose

- weather prtection clothes

  used against: rain, wind, ice, snow, coldness

1.2. Capital and operation related costs

The capital and operation related costs of some weather protection facilities are specified in table 1.

For better comparison, the costs are given in US dollars per square foot of floor area, too.

Table 1: Capital costs and operation related costs of some weather protection facilities

type of weather protection facility	floor area	capital costs related to 1972		operation related costs per year						
	sq. ft.	US $	US $ per sq. ft.	repairing US $	maintenance US $	heating US $	illuminat. US $	insurance US $	total US $	US $ per sq. ft.
hall with fixed roof	15,000	95,000	6.33	2,400	1,250	2,400	500	320	6,870	0.46
hall with traversing roof	14,500	170,000	11.72	2,500	1,750	2,400	450	520	7,620	0.53
movable hall	3,200	10,000	3.13	930	310	-	160	125	1,525	0.48
portable roof	900	1,500	1.67	130	40	-	-	-	170	0.19
weather protection clothes (for 50 workmen)	-	1,550	-	160	-	-	-	-	160	-

NOTE: The above costs are for individual buildings and are not necessarily representative of capital and operating costs for buildings.

2. Methods and procedures of weather protection for personnel and material in the European heavy construction industry. Improvements in productivity and costs.

A special analysis of this branch has not been made, because many of the European shipyards build not only ships, but also docks, heavy steel constructions, apparatus, machines, etc.

Thus the conditions for the use of weather protection facilities are nearly the same.

3. Effects of weather protection facilities on productivity and costs in the European shipbuilding industry.

- Advantages and disadvantages in the use of weather protection facilities -

3.1 Advantages

- better working conditions
- better working quality
- no interruption of work by adverse weather conditions
- lower uncertainty in work planning
- no schedule delays
- increase of working efficiency
- lower production costs

- no removal of rain water, snow, ice
- less or no removal of dirt, dust, rust
- less or no preheating (when welding high tensile steel or painting)
- longer life span of shipbuilding tools and apparatus
- lower accident rate
- lower sickness rate
- possibility of working without daylight
- possibility of welding high tensile steels
- possibility of sand blasting
- possibility of using automatic devices (e.g. submerged arc welding or gas-shielded arc welding)
- better possibility of control

3.2 Disadvantages

- narrow working space
- low height of crane hook (in halls with overhead travelling cranes)
- draft
- more heat
- more noise
- more welding and burning gases in the air
- more dust in the air during cleaning work

4. Increases of worker productivity obtained in the European shipbuilding industry by the use of weather protection.

4.1 Productivity per shift and worker

		without weather protection facilities in adverse weather conditions (snow, ice, rain, storm)	with Weather protection facilities
		linear ft.	linear ft.
welding	manual	65	120
	automatic	240	430
burning	manual	180	360
	automatic		570
		Sq. ft.	Sq. ft.
painting (including preliminary work such as derusting etc.)			
	manual	220	480
	with spray gun	380	760

The shipyards took the above figures from their production records.

Since thin plates afford a larger, and thick plates a smaller welding and burning productivity measured in linear ft., an average plate thickness has been assumed.

Figures for welding were assumed to be one run of welding.

Figures for painting were assumed for one coat film of the average thickness.

The significant difference between working productivities with and without weather protection facilities will of course decrease if better weather conditions are anticipated (see 4.2).

4.2. Productivity.per year

(basis for productivity without weather protection facilities = 100)

	without weather protection facilities	with weather protection facilities
marking	100	150
burning	100	165
assembling includixxg tack welding	100	140
welding	100	165
painting including preliminary work	100	170
other shipbuilding activities	100	135

The above figures have been estimated by the shipyards.

5. Additional work requirements and costs in European shipbuilding caused by environmental extremes

removal of

- - dirt
- - dust
- - scale
- - rust
- - rainwater
- - snow
- - ice

- proheating for
  - - welding
  - - painting

more loss and repairing and maintenance of shipbuilding tools and apparatus

more 10ss of materials, e.g. welding electrodes and welding wire

- arrangement of safety devices to prevent damage by wind, storm, etc.

6. <u>Secondary cost effects on worker productivity resulting from environmental extremes</u>

6.1 <u>Accident ratos</u>

(basis for accident rate without weather protection facilities = 100)

	without weather protection facilities	with weather protection facilities
in summer	100	95
in winter	100	75
throughout the year	100	85

6.2 Sickness rates

(basis for sickness rate without weather protection facilities = 100)

	without weather protection facilities	with weather protection facilities
in summer	100	95
in winter	100	75
throughout the year	100	85

The above figures have been estimated by the shipyards.

C. Conclusion

Shipbuilding in Europe is shifting to an increasing extent from non-protected open-air space to weather protected areas.

Weather protected facilities ensure improvements in working productivity and working conditions.

Especially small and middle sized shipyards with adverse climate conditions, e.g. Amels, IHC-Smit and Linz shipyards (see literature), have erected and put into operation halls

for shipbuilding activities, which had been done in open air space before. In some cases even building docks and slip way areas have been covered by weather protection devices.

Most of the larger shipyards in Northwest Europe however, could not, or only partly, realize this idea of total inside shipbuilding up to now, because the capital costs for such great halls, covering the whole building areas, are too high in relation to the attainable output. The shipyards, in many cases, also have not got enough orders to justify such investments.

D. Literature about Weather Protection

1. "Überdachtes Baudock bei der Amels-Werft in Makkum"
   - HANSA 1971, Nr. 21. p. 2096 -

2. "Binnenschiffbau in der Halle"
   - Schiff und Hafen 1972, Nr. 4, p. 247 - 249

3. "Überdachte Helling bei IHC Smit"
   - HANSA 1972, Nr. 24, p. 2270 - 2271

4. "Reconstruction of Öresundsvarvet"
   - Schiff und Hafen, 1970, Nr. 11, p. 1038 - 1040

Copies of these articles are attached, additional English summaries of articles 1, 2, and 3.

Überdachte Helling bei IHC Smit
- Hansa 1972, No. 24, p. 2270 - 2271

Roofed Building Slip at IHC Smit Shipyard (Netherlands)
(English Summary)

The former shipyards L. Smit and J. + K. Smit, Kinderdijk, have been united to one shipyard within the IHC-Group since 1967.

The different situated local workshops require a reorganization of the entire shipyard and also the way of production. Shipbuilding should be accomplished without the influence of adverse weather conditions and rationalized to a high degree so that personnel savings can be obtained. Workmen are no longer willing to do shipbuilding work at unprotected and narrow places.

The new shipbuilding hall, existing of three naves, was finished in October 1972. Consequently the whole steel shipbuilding up to launching can be accomplished inside the Hall.

The third nave covers the building slip, which has a bulkheading against the outside water in form of a pontoon. Ships with the dimensions of 459.2 ft. x 75.4 ft. can be built on the building slip.

The dimensions of the hall are 551.0 ft. x 167.3 ft. x 111.5 ft.

Ventilation is obtained through two ventilation channels, respectively 14 exhaustors, which are fixed within the roof. The hall can be heated by infra-red heating devices.

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101-76
Volkers
Reg. (2)

Überdachtes Baudock bei der Amels-Werft in Makkum
- Hansa 1971, No. 21, p. 2096

Roofed Building Dock at Amels Shipyard, Makkum (Netherlands)

In 1968 Makkum Shipyard started a large program of modernization. The first part of this program was completed in November 1971.

The main investments are a roofed building dock with the dimensions of 393.6 ft. x 62.3 ft. x 23.0 ft. and a hall of 413.3 ft. x 121.4 ft. x 93.5 ft. Thus, all shipbuilding works can be accomplished without the influence of adverse weather conditions. The dock floor is situated 16.4 ft. below the outside water level, so even ships which are nearly fully fitted out, can be floated up inside the hall.

The hooks of the overhead travelling hall cranes are 72.2 ft. above the floor of the hall, respectively 95.1 ft. above the floor of the building dock.

At both ends of the hall there are sliding doors with a clear width of 60.7 ft. installed. The doors are driven electrically and tele-controlled.

Above the sliding doors, which reach up to the crane track, there are wing doors installed. When these wing doors are opened, the overhead travelling cranes can roll out of the hall on crane tracks nearly 45.9 ft.

The hall is illuminated by 125 mercury vapour lamps of 1000 watt each and through plastic windows of 21.3 ft. breadth in the walls. Ventilators are installed within the roof of the hall. The hall can be heated in the winter.

It is planned to lengthen the building dock 262.4 ft. and the hall 426.4 ft.

V-61.847
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101-76
Volkers
Reg. (2)

Binnenschiffbau in der Halle

- Schiff und Hafen 1972, No. 4, p. 247 - 249

Building of River Vessels inside Halls

(English Summary)

On March 11, 1972, the Linz Shipyard (Austria) put into service a new shipbuilding hall (see plan, Hall No. IV).

There were several reasons for building the hall and altering the conventional procedure of shipbuilding:

- Shipbuilding should be accomplished without the influence of adverse weather conditions. It is very difficult to obtain qualified workmen who are willing to do the hard shipbuilding job in unprotected open air space.

- Increasing building costs should be stopped as far as possible by more productivity.

- There should be no uncertainty in work planning, which is very often the result of adverse weather conditions.

- Better quality of work should be achieved.

- The conditions of competition should be improved.

Technical data of the shipbuilding hall:

Dimensions:

Length: 328.0 ft; breadth: 114.8 ft; height: 78.7 ft.

Cranes: Two overhead travelling cranes of 40/10 t each, one crane of 10 t. Height of crane hook: 46.6 ft.

Sliding doors:
Dimensions:
west doors: 39.4 ft. x 53.8 ft; 39.4 ft. x 51.2 ft.
east door: 23.0 ft. x 52.5 ft.

Heating: 20 air heating devices of 353,149 cu. ft./hour.

The dimensions of the halls allow to build two river vessels of European type (Europa-Type) (278.8 ft. x 31.2 ft.) side by side.

The ships are completely outfitted in the hall and then brought out by rail cars.

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Volkers
(Reg. 2)

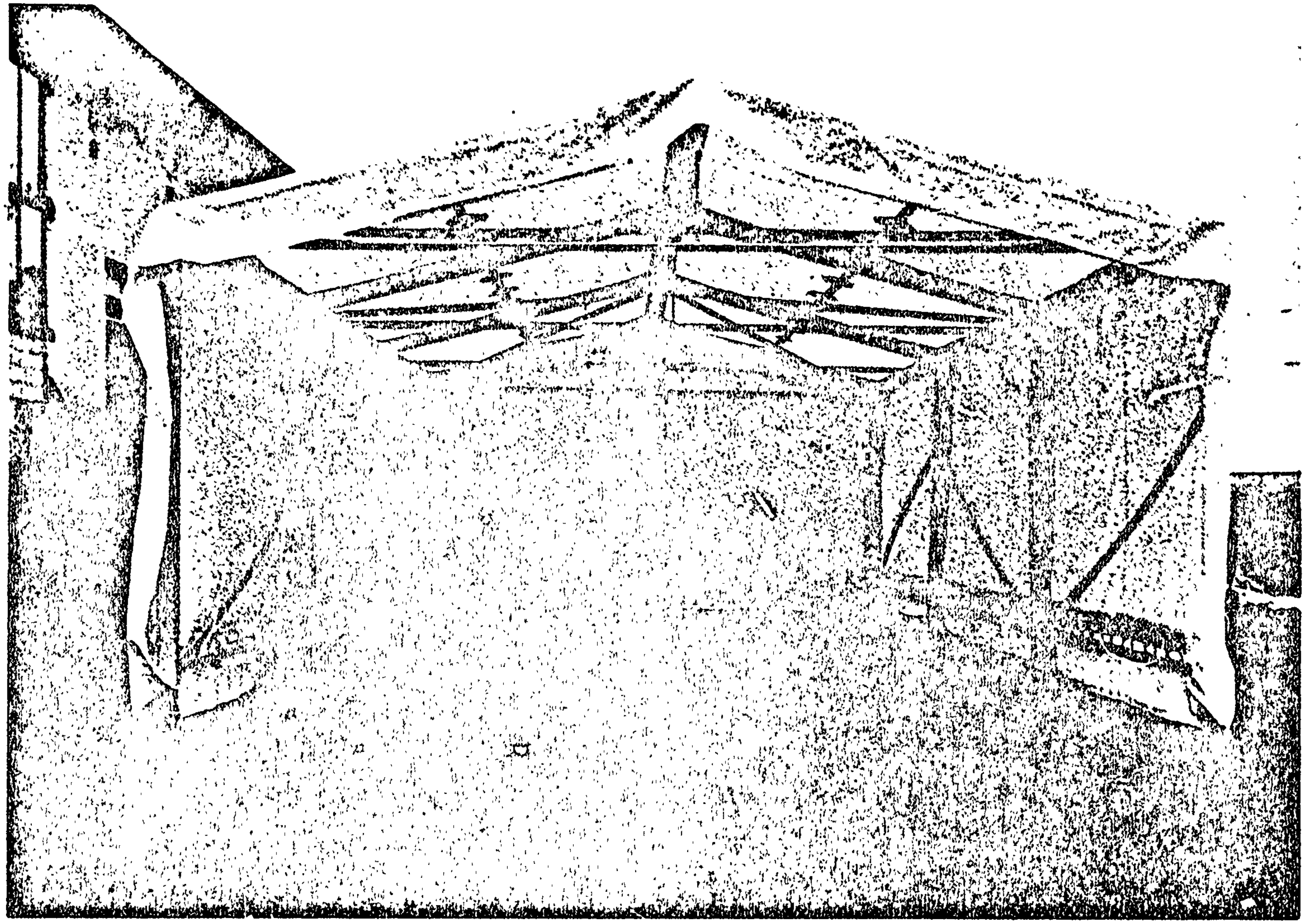


Figure I-1 - Lightweight canvas-covered portable shelter supported on rubber tired wheels. These unique wheeled buildings are manufactured by Josef Wirtz and Co. GmbH in Germany and have seen use in European shipyards.

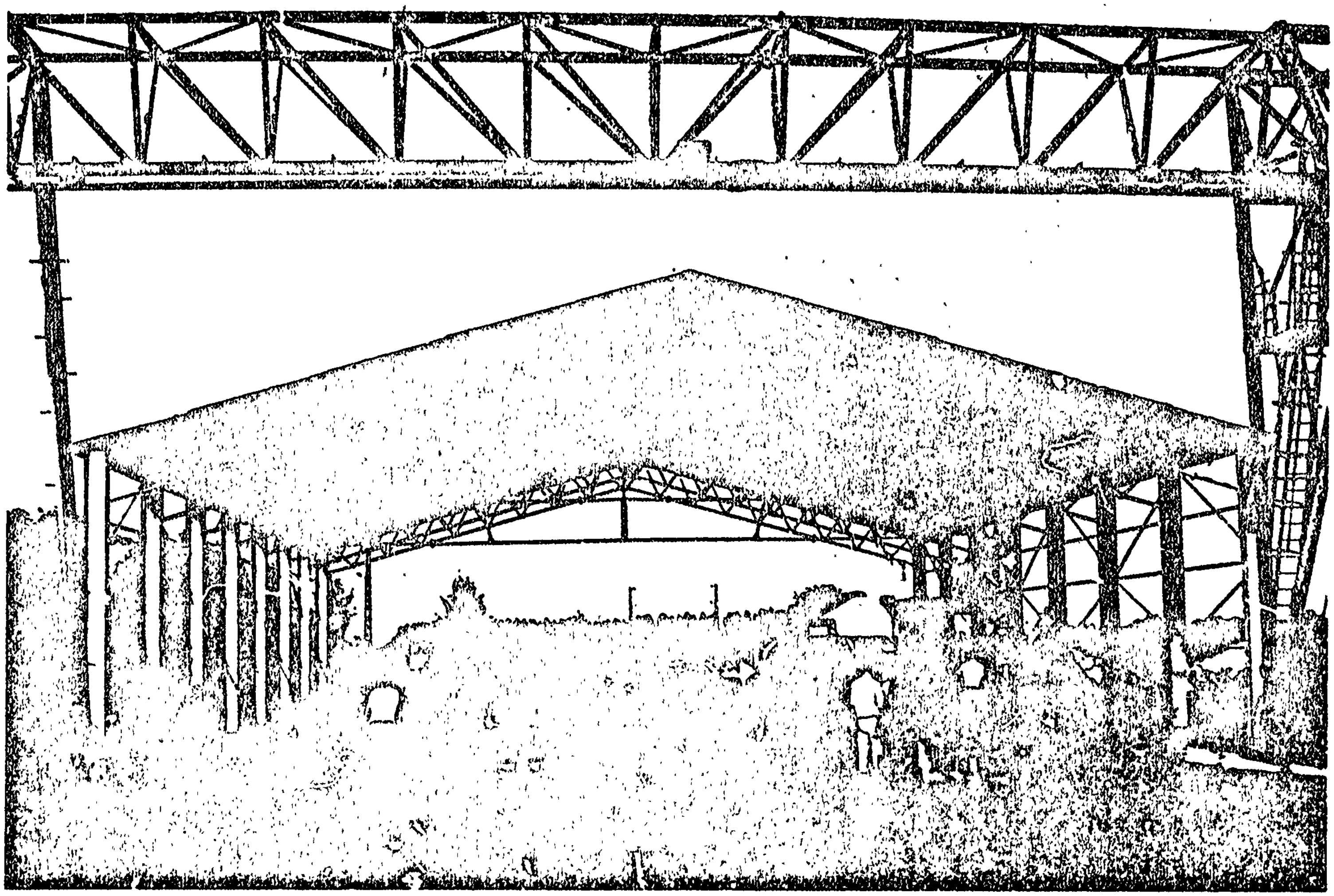


Figure I-2 - A movable hall, supported on wheels. These wheeled buildings may have sheet metal or canvas sides or ends, or be open as shown. They are manufactured by Josef Wirtz and Co. GmbH, Germany and have been used in European Shipyards and construction industry.

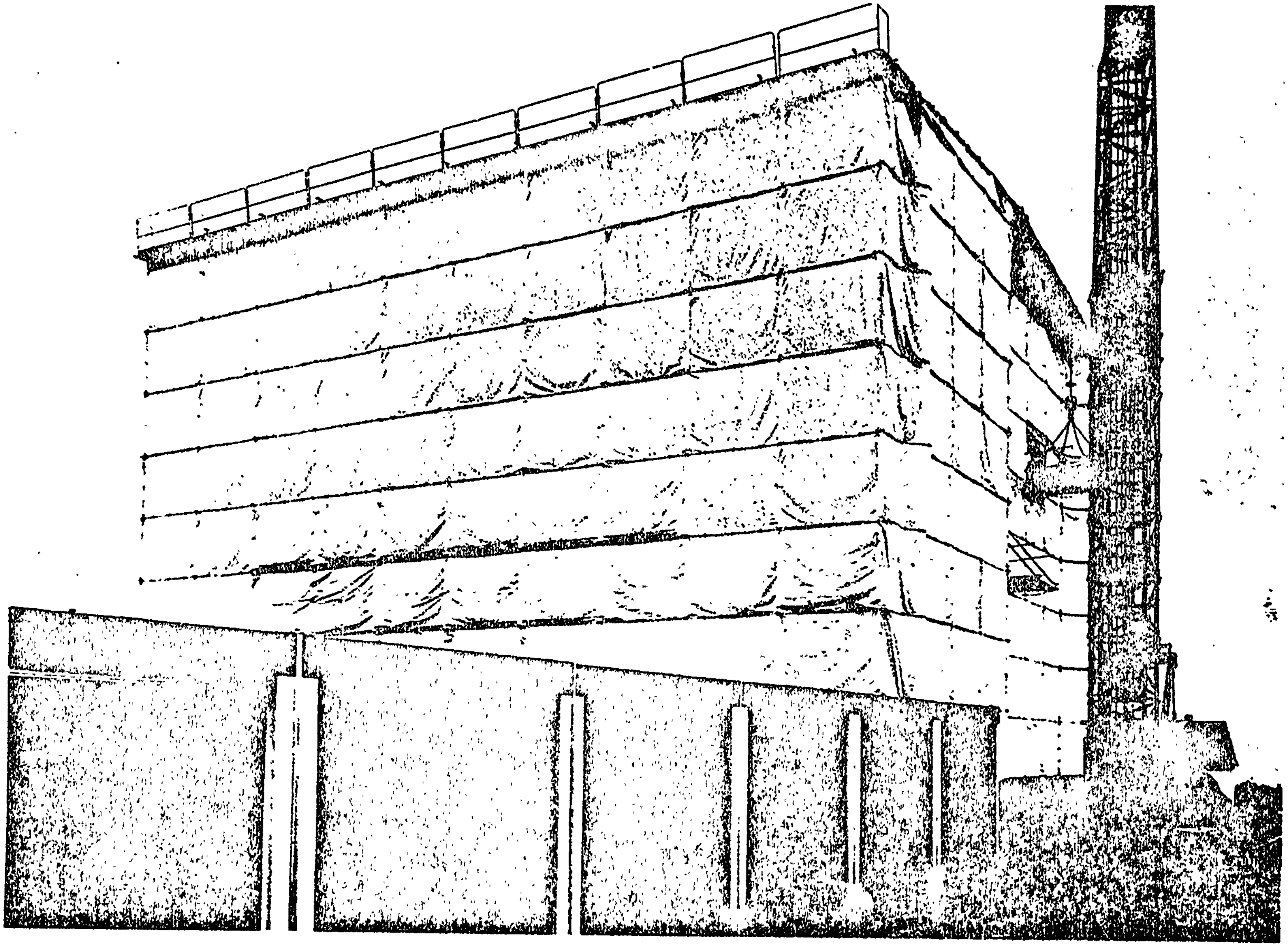


Figure I-3 - An example of the use of hoarding panels for weather protection in heavy construction in Germany. Note the access for materials delivery. These are called CENO plastic tilts and Carl Nolte, Germany is the patentee of this particular system. The fabric is reinforced PVC and is translucent.

APPENDIX J

DESCRIPTION OF THE STANDARD SHIPYARD

General

The productivity models were applied to a hypothetical "Standard" shipyard to obtain estimates of the cost effectiveness of various categories of weather protective structures. The purpose of the standard shipyard was to provide a yardstick against which anticipated benefits of this and other R&D programs could be measured. The standard shipyard description was provided by J. J. McMullen Associates as a part of a study on "Ship i'roductivity - Determination of Task Priorities." It describes both a "standard" shipyard and a "standard" ship.

The standard ship is a "Panamax" type of tanker with an overall length of 820 feet, a breadth of 105 ft, a depth of 60 ft and a displacement of 91,250 tons. Other particulars of the ship and its construction which are pertinent to this study are shown in tables in the following sections.

It should be pointed out that the "standard" shipyard is entirely synthetic having been created from a number of basic production requirements constrained by a number of typical environmental factors; although it is intended to be a standard United States shipyard, rather than a foreign one, any resemblance to any other shipyard, whether existing or defunct, is purely coincidental. It should be kept in mind that it is a tool for comparative analyses and is not intended to be an "optimum" shipyard.

The descriptions of the standard ship and the shipyard which follow are extracted from the J. J. McMullen Associates report.

The Standard Ship

The principal particulars of the standard ship, a "Panamax" tanker, are given in Table J-1. It is a traditionally high quality, subsidized construction vessel built to American Bureau of Shipping rules and conforming to all the usual requirements for U.S. flag operation.

A simplified breakdown of construction cost is presented in Table J-2 and expanded in Table J-3. Both of these exhibits display the elements of cost as percentages of the total: Table 5 converts the detailed data of Table J-3 to dollars, assuming that the total price for one ship in a continuous series is $26,750,000 in mid-1973.

The weight breakdown of the seven steel classifications has been derived separately and is shown in Table J-5.

The Standard Shipyard

In formulating the standard shipyard, it was assumed that the standard shipyard, although built before World War II, has modernized its facilities to the fullest extent possible given its geographical and structural limitations.

It was also assumed that the shipyard has an annual steel throughput of approximately 40,000 tons, equivalent to three standard ships a year.

Table J-1

DESIGN FEATURES OF A STANDARD 75,000 DWT TANKER

Length Overall	820' - 0"
Length B.P.	780' - 0"
Breadth	105' - 0"
Depth	60' - 0"
Draft, full load	45' - 0"
Steel weight, tons	13,500
Outfit weight, tons	1,750
Machinery weight, tons	1,000
Lightship, tons	16,250
Deadweight, tons	75,000
Displacement, tons	91,250
Machinery	Geared steam turbine
SHP	20,000
Propellers	1
Speed, design, knots	16
Bunkers, tons	5,000
Endurance, miles	15,000
Pumps	3
Pump size, GPM	6,500
Cargo tanks	7
Accommodation	Aft
Classification	ABS
Registry	US
Crew	30

TOTAL PRICE BREAKDOWN

(Simplified)

	26.31 %
Direct Material	50.00
Total Direct Cost	76.31
Indirect	5.26
Engineering	2.63
Construction Cost	84.20
overhead	15.80
Total Cost	100.00
Profit	12.63
Total Price	112.63 %

Table J-3

TOTAL PRICE BREAKDOWN
(Detailed)

DESCRIPTION	MATERIAL $	LABOR $
Shell Plating	5.31	4.25
Bulkheads and Pillars	4.56	3.08
Frames	6.64	5.14
Deck Plating and Beams	4.24	2.05
Superstructure	.55	1.55
Foundations	.14	.85
Castings	.70	.21
Total Steel	22.14	17.13
Masts and Rigging	.09	.05
Hatch Covers and Beams	---	---
Anchors, Cables and Hawsers	.75	.03
Hull Attachments and Joinerwork	3.05	.71
Generators and Distribution	2.15	.97
Reefer and Air Conditioning	.30	.07
Deck Auxiliaries	2.15	.19
Navigation and Steward's Outfit	.45	.16
Hull Plumbing	3.65	1.86
Ventilation	.40	.47
Paint	2.51	2.35
Total Outfit	15.50	6.86
Main Engine and Shafting	5.08	.23
Boilers, Fuel and Steam Systems	4.76	1.51
Pumps and Compressors	1.56	.07
Engineroom Outfit	.96	.51
Total Machinery	12.36	2.32
Total Labc-		26.31
Total Material		50.50
Total Direct Cost		76.31
Indirect		5.26
Engineering		2.63
Construction Cost		84.20
Depreciation	2.11	
Fringe Benefits	6.32	
Other	7.37	
Total Overhead		15.80
Total Cost		100.00
Profit		12.63
Total Price		112.63

Table J-4

TOTAL PRICE BREAKDOWN

DESCRIPTION	MATERIAL $	LABOR $
Shell Plating	1,262,500	1,010,000
Bulkheads and Pillars	1,085,000	732,500
Frames	1,577,500	1,220,000
Deck Plating and Beams	1,007,500	487,500
Superstructure	130,000	367,500
Foundations	32,500	202,500
Castings	165,000	50,000
Total Steel	5,260,000	4,070,000
Mast and Rigging	22,500	12,500
Hatch Covers and Be.ms	--	--
Anchors, Cables and Hawsers	177,500	7,500
Hull Attachments and Joinerwork	725,000	167,500
Generators and Distribution	510,000	230,000
Reefer and Air Conditioning	70,000	17,500
Deck Auxiliaries	510,000	45,000
Navigation and Steward's Outfit	107,500	37,500
Hull Plumbing	867,500	442,500
Ventilation	95,000	112,500
Paint	595,000	557,500
Total Outfit	3,680,000	1,630,000
Main Engine and Shafting	1,207,500	55,000
Boilers, Fuel and Steam Systems	1,130,000	357,500
Pumps and Compressors	370,000	17,500
Engineroom Outfit	227,500	120,000
Total Machinery	2,935,000	550,000
Total Labor		6,250,000
Total Material		11,875,000
Total Direct Cost		18,125,000
Indirect		1,250,000
Engineering		625,000
Construction Cost		20,000,000
Depreciation	509,000	
Fringe Benefits	1,500,000	
Other	1,750,000	
Total Overhead		3,750,000
Total cost		23,750,000
Profit		3,000,000
Total Price		$26,750,000

Table J-5

STEELWEIGHT BREAKDOWN

	TONS
Shell plating	3,375
Bulkheads and pillars	2,862
Frames	3,888
Deck plating and beams	2,660
Superstructure	500
Foundations	108
Castings	107
	13,500

The direct labor requirements of this rate of production are given in Table J-6. The direct labor costs in dollars from Table J-4 have been converted into manhours using an average rate of $4.60, the projected average hourly rate for the United States shipbuilding industry at mid-1973, and the results have been multiplied by three to reflect the assumed output of three ships a year. In the second column, these manhours have been expressed as a percentage of total direct labor manhours~ and in the third column they have been divided by 2000 to arrive at the equivalent number of direct labor employees required. The total in this column shows an average direct labor requirement of 2038 workers.

The required direct labor workforce shown in Table J-6 is presented again in Table J-7 in such a way as to demonstrate the distribution of manpower both by function and work location.

It was further assumed that the standard shipyard is engaged in merchant ship construction only and all,naval and repair work is contained within a separate and distinct organization.

Although virtually all United States shipyards are involved simultaneously in both merchant and naval shipbuilding and ship-repairing, the impacts of cost reduction tasks on commercial ship costs can only be effectively evaluated if those costs are isolated from the shipyard's other activities. The implication of this assumption for the definition of the standard shipyard is that the labor force is perfectly balanced and fully occupied, a condition that can only be true in a shipyard building a single Product, a standard ship, since variations in product mix inevitably result in variations in labor function requirements.

Table J-6

LABOR REQUIREMENTS

CLASSIFICATION	Annual Direct Labor Manhours	% of Total Direct Labor	Equivalent # of Men
Shell Plating	658,700	16.2	329
Bulkheads and Pillars	477,700	11.7	239
Frames	795,600	19.5	398
Deck Plating and Beams	317,900	7.8	159
Superstructure	239,700	5.9	120
Foundations	132,100	3.2	66
Castings	32,600	.8	16
Total Steel	2,654,300	65.1	1,327
Masts and Rigging	8,200	.2	4
Hatch Covers and Beams	--	--	--
Anchors, Cables and Hawsers	4,900	.1	2
Hull Attachments and JoinerWork	109,200	2.7	55
Generators and Distribution	150,000	3.7	75
Reefer and Air Conditioning	11,400	.3	6
Deck Auxiliaries	29,300	.7	15
Navigation and Stewards Outfit	24,400	.6	12
Hull Plumbing	288,600	7.1	144
Ventilation	73,400	1.8	37
Paint	363,600	8.9	182
Total Outfit	1,063,000	26.1	532
Main Engine and Shafting	35,900	.9	18
Boilers, Fuel and Steam Systems	233,100	5.7	116
Pumps and Compressors	11,400	.3	6
Engineroom Outfit	78,300	1.9	39
Total Machinery	358,700	8.8	179
TOTAL	4,076,000	100.0	2,038

Table J-7

DIRECT LABOR DISTRIBUTION

Location / Function	Steel Fabrication & Related Shops	Steel Assemby Shops and Areas	Departmental Shops	Machinery Assembly Shops	Shipway	Outfitting Wharf	Totals
Steelwork	200	400	---	7	700	20	1327
Electrical	---	10	8	2	35	20	75
Piping	4	20	74	8	24	14	144
Sheetmetal	---	10	14	2	20	4	50
Joinerwork	---	---	10	--	15	20	45
painting	4	40	4	--	110	24	182
Machinery	---	20	12	40	48	59	179
Other	---	---	4	--	20	12	36
Totals	208	500	126	59	972	173	2038

The support workforce required by a standard shipyard with a direct labor workforce of 2038 was defined as 458 additional employees (for a total of 2496).

This proportion represents the position of the standard shipyard as an approximately average yard in the spectrum of United States shipbuilding. Indirect, engineering and overheads, which include the cost of the support workforce are shown in Table J-8.

Facilities and Production Processes in the Standard Shipyard

Steel arrives"by rail and is unloaded and sorted by a gantry magnet crane in a stockyard of about 60,000 square feet, employing a horizontal storage and having a capacity for one shipset of steel. The standard plate size is 45 feet by 10 feet, although the maximum could be 48 by 12. This standard size is directly related to the design of the standard ship, 45 feet being one half of the tank length, and hence to the panel construction method.

The steel is fed by convejor, via a surface preparation line involving the usual cleaning, mangling, blasting, painting and drying processes, into a fabrication shop of about 40,000 square ieet, divided into four bays, equipped for sections, flat panel material, shaped panel material and the remainder. The fabrication shop is equipped with the conventional cold forming machinery, template-controlled, and automatic burning machinery, optically-controlled. There is no numerical control. An overhead crane of 15 tons spans each bay.

Table J-8 INDIRECT, ENGINEERING AND OVERHEAD COSTS

(MARAD GROUPINGS)

	% of Costs	Cost in $.	Equivalent # of Men
Indirect Costs			
Insurance and bond premia, fees for classification and testing, royalties of a general nature.	.26	$ 187,500	--
Drydocking, launching trials and delivery costs, including supplies, catering, trials personnel, pilots, tugs, calibration, etc.	.79	562,500	--
Miscellaneous labor for ship cleaning, toolrooms, watchmen, materials handling, supervision, industrial engineering functions.	2.63	$1,875,000	200
Sundry other items, including travel, temporary services, weather protection, fire prevention, gasfreeing and analysis, photography.	1.58	$1,125,000	20
	5.26	$3,750,000	220
Engineering Costs			
Drawings, calculations, yard liaison, purchase requisitions, tests, microfilming, model testing, outside professional services.			
	2.63	$1,875,000	80
Overhead Costs			
Depreciation, insurance and taxes.	2.11	$1,500,000	--
Maintenance and repair of all property, buildings, machinery and equipment, fixed or portable.	2.11	$1,500,000	18
Wages and salaries of all other personnel, including management, departmental supervision, clerical staff, maintenance personnel, crane operators, storekeepers, drivers, production planning, welfare services and administration.	2.63	$1,875,000	100
Supplies of services and maintenance and administrative requirements.	1.58	$1,125,000	--
Fringe benefits, including vacation and holiday pay, bonuses, social security, life insurance, unemployment tax, workmen's compension, sick benefits, excused time, etc.	6.32	$4,500,000	--
Miscellaneous other costs, including accidents, losses, welfare, travel, R and D, estimating, advertising, etc.	1.05	$ 750,000	40
	15.80	$11,250,000	158
Total indirect, engineering and overhead:	23.69	$16,875,000	458

The section and flat panel material bays lead into a flat panel assembly shop of about 20,000 square feet, featuring eight working areas, of 2,500 square feet each, for the construction of flat panels of plating with associated longitudinal and transverse framing, up to a maximum size of 48 feet by 30 feet, and averaging 60 tons each. Welding is semi-automatic, both of plate-butts and of stiffening, and material is moved and positioned using three overhead cranes, two of 75 tons and one of 15 tons. Average panel construction time is four to five days. The other two fabrication bays lead into a shaped panel assembly shop, also of about 20,000 square feet, where working areas are laid out as required for the more complex shaped panels. Welding is semi-automatic or manual and material is moved and positioned by means of similar cranage to the flat panel shop. Average panel construction time is eight to ten days.

All completed steel assemblies are moved outside to a paint shop where welds are cleaned and painted and then to storage areas or directly to the shipways: multi-wheel heavy-load transporters are used for these movements.

Machinery and outfit materials are received both by road and by rail and held in conventional warehousing and other storage areas until required. Machinery and outfit “work packages” are put together in-various shops, mostly of an earlier generation, and delivered to work stations by truck or forklift. “These packages are normally but not necessarily trade-oriented: they may include material for several different operations planned to take place in the same work place. Limited panel outfitting takes place in the

steel assembly shops, being confined to the fitting of attachments for piping, cable trays and ventilation ducting.

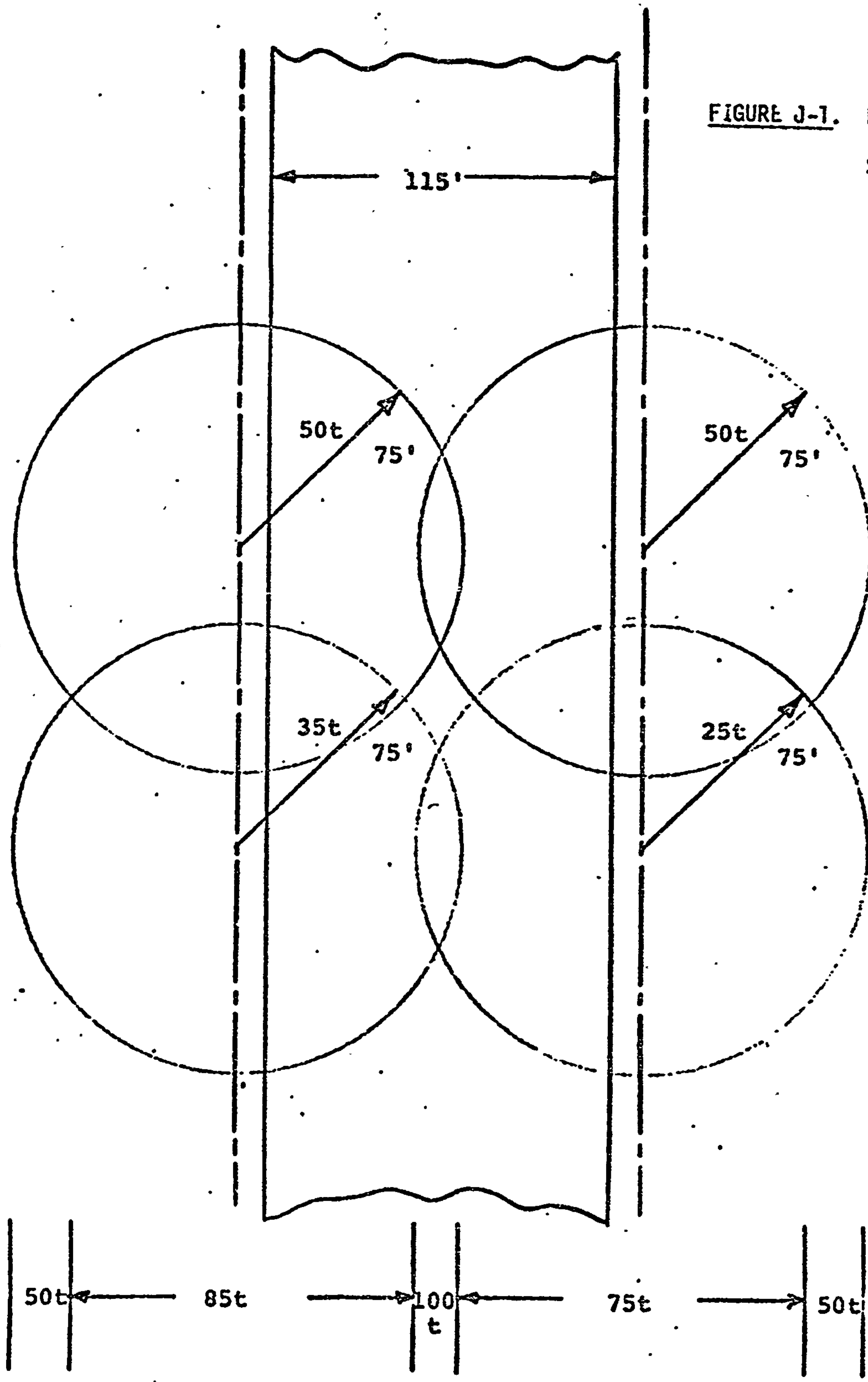
Ship erection is carried out on one of two shipways, starting with stern panels and working forward and upward. Each shipway is big enough for the standard ship with a working margin of five feet on each side and thirty feet on the length but no more. Each is served by four whirley cranes:

- two of 50 tons max. lift at 75 feet max. outreach
- one of 35 tons max. lift at 75 feet max. outreach
- one of 25 tons max. lift at 75 feet max. outreach

as shown in the sketch presented as Figure J-1. Average erection time is eight months at an average work rate of approximately on: panel per day.

After launching.aunching, each ship is moved to a single outfit wharf where its stay averages four months.

FIGURE J-1. Berth Cranage In the Standard Shipyard



MINIMUM LIFT CAPACITIES

Outdoor Operations in the Standard Shipyard

The indoor operations and facilities and the outdoor shipways are described in the preceding pages.

The approximate uses and areas for outdoor operations which could be covered for weather protection were assumed to be in the ranges shown below:

Description	Area
Steel stockyard operation	60,000 sq.ft.
Machinery and outfit storage areas for bulky items of a non-weather-sensitive nature	As required
Cleaning and painting of welds on steel assemblies	10,000 Sq.ft. minimum
Panel storage (or module assembly, if desired) with associated pre-outfitting (if not completed in the assembly shop) or further pre-outfitting following mudule assembly including fitting of as many of the following items as seems appropriate to the shipyard management:	20,000 Sq.ft. minimum, up to 80,000 sq.ft.

- pipes
- valves and other pipefittngs
- ventilation ducts
- cable trays
- cable runs
- doors
- manholes
- skylights
- hull openings
- heating coils
- interior painting
- exterior painting
- machinery room outfit
- accommodation fitting to the extent that it is possible.

DIRECT LABOR DISTRIBUTION IN THE STANDARDS SHIPYARD

The distribution of direct labor in the standard shipyard by craft and location is shown in Tables J-9 through J-11 for steel work, machinery work and outfit work. This distribution was used in the productivity model.

Table J-9

DIRECT LABOR DISTRIBUTION FOR STEEL WORK

Function \ Location	Steel Fabrication & Related Shops	Steel Assembly Shops & Areas	Departmental Shops	Machinery Assembly Shops	Shipway	Outfitting Wharf	Totals
Burners & Welders	a:60	160 {a:80, b:80}	-	a:4	287 {b:110, c:177}	30 {b:8, c:22}	541
Blasters & Painters	10 {a:5, b:5}	b:10	-	0	25 {b:20, c:5}	15 {b:7, c:8}	60
Fitters	a:107	187 {a:87, b:100}	-	a:2	285 {b:113, c:172}	25 {b:6, c:19}	606
Riggers	20 {a:18, b:2}	40 {a:20, b:20}	-	a:1	39 {b:14, c:25}	8 {b:2, c:6}	108
Other Crafts	a:3	b:3	-	0	b:4	c:2	12
TOTALS	200	400	-	7	640	80	1327

a. In the shop
b. Outside not protected from weather
c. " but " by ship structure

Table J-10

DIRECT LABOR DISTRIBUTION FOR: MACHINERY WORK

Location / Function	Steel Fabrication & Related Shops	Steel Assembly Shops & Areas	Departmental Shops	Machinery Assembly Shops	Shipway	Outfitting Wharf	Totals
Burners & Welders					b:1/c:1	c:6	8
Blasters & Painters					c:1	c:3	4
Fitters							
Riggers					b:6/c:2	c:4	12
Other:							
Pipefitters			a:15		b:6/c:22	c:40	83
Electricians			a:4		c:12	c:24	40
Machinists				a:6	b:8/c:4	c:6	24
Sheet Metal Wkrs.			a:1		c:2	c:5	8
TOTALS	-	-	20	6	65	88	179

a. In the shop
b. Outside not protected from weather
c. " but " by ship structure

Table J-11

DIRECT LABOR DISTRIBUTION FOR: OUTFIT WORK

Location / Function	Steel Fabrication & Related Shops	Steel Assembly Shops & Areas	Departmental Shops	Machinery Assembly Shops	Shipway	Outfitting Wharf	Totals
Burners & Welders	a:4	a:8			b:10/c:30	b:18/c:36	106
Blasters & Painters		a:1	a:1		b:3/c:7	b:15/c:15	42
Fitters	a:2	a:6			b:7/c:14	b:11/c:24	64
Riggers		a:1	a:3		b:4/c:8	b:13/c:13	42
Other:							
Pipefitters			a:35		b:8/c:52	b:10/c:30	135
Electricians			a:6		b:1/c:9	b:6/c:62	84
Machinists					b:2	b:4	6
Sheet Metal Wkrs.			a:13		c:4	b:2/c:34	53
TOTALS	6	16	58	-	159	293	532

a. In the shop
b. Outside not protected from weather
c. " but " by ship structure

APPENDIX K

ANALYSIS OF COSTS FOR THE STANDARD SHIPYARD

COSTS AFFECTED BY LABOR PRODUCTIVITY

Lower labor productivity and lost time can increase shipbuilding costs in several ways (Table K-1). The potential magnitude of these costs for the standard shipyard are described and calculated in this section.

TABLE K-1. Increased Costs Caused by Lost Time or Lower Productivity

A. Shipyard capacity not fully realized.

1. Land is occupied longer than needed.
2. Building space is occupied longer than needed.
3. Equipment and facilities not used to capacity.
4. Inventory costs for work-in-process are higher.
5. Overhead cost allocated over a reduced production.
6. Extra capacity is required to meet peak operating rates.

B. Unit labor costs increase.

1. Payments for idle time not worked.
2. Lower output/man-hour.
3. Reject and rework cost.
4. Premium pay for call-in or overtime.

The cost distribution for the standard shipyard was shown in Table J-6 and Table J-8, Appendix J. The total annual costs for the standard shipyard are $80,210,000. The overhead costs were distributed into material-related, labor-related, related to selling price, and fixed period costs as shown in Tables K-2 and K-3. The costs related to selling price in Table K-3 were redistributed proportionally to the other three. After this redistribution, the percentage breakdown of costs in the model shipyard were: labor-related, 37.4%; material-related, 54.2%; and fixed, 8.4%.

TABLE K-2. Distribution of Indirect and Overhead Costs

Indirect Cost	% of Costs	Nature of Variability
Insurance & Bond Premium, etc.	0.26	Fixed percentage of selling price
Drydocking, etc.	0.79	Fixed percentage of selling price
Misc. Labor, etc.	2.63	1/2 Variable with direct labor cost - 1/2 fixed annual
Sundry Other Items, etc.	1.58	3/4 Fixed annual expense - 1/4 to direct labor
Engineering Costs	2.63	Fixed percentage of selling price
Overhead Costs		
Depreciation, etc.	2.11	Fixed annual expense (varies with capital investment)
Maintenance, etc.	2.11	Fixed annual expense (varies with capital investment)
Wages, etc.	2.63	Fixed percentage of selling price
Supplies, etc.	1.58	Fixed percentage of selling price
Fringe Benefits, etc.	6.32	Variable with direct labor cost
Misc. Other, etc.	1.05	Fixed annual expense
Profit	12.63	Fixed percentage of selling price

TABLE K-3. Distribution of Annual Costs in the Standard Shipyard

Construction Schedule = 3 ships 1 year

Expense	One Ship	Three Ships	%
Direct Labor	6,250,000	18,750,000	24
Labor Burden	1,910,000	5,730,000	7
Direct Material	11,875,000	35,600,000	44
Fixed Annual	1,840,000	5,520,000	7
Related to Selling Price	4,870,000	14,610,000	18
	26,675,000	80,210,000	100

Only the labor-related costs, 37.4% of the annual shipyard costs, vary directly with labor productivity. This percentage was used to determine the minimum cost savings achieved through productivity gains. The minimum cost does not include any extra provisions for hiring or training costs. The maximum cost savings are derived from the elimination of overtime premium pay and are calculated at 60% of the annual shipyard costs.

Intermediate cost savings would result from an increase in the production rate of the shipyard. Fixed costs per unit of production would be reduced. Interest expense on working capital would be reduced since the production schedule would be shortened. The calculation below of interest expense on working capital assumes reduction of four months covering 90% of the costs, since a large fraction of the costs, primarily for steel, are committed early in the shipbuilding schedule.

CALCULATIONS OF THE EFFECT OF LABOR PRODUCTIVITY ON SHIPBUILDING COSTS

Costs to regain lost productivity are calculated below for three different assumptions. The typical shipyard experience is probably a mixture of all these cases with some additional cost factors not specifically included here.

Maximum Cost Case

1. If the productivity deficit is made up by overtime - assuming minimum pay of time-and-one-half: then the increased cost to achieve the required output would be 1-1/2 times the straight time labor-related costs, or

$$0.374 \times \frac{1\text{-productivity}}{\text{productivity}} \times 1\ 1/2 = 0.561 \times \frac{1\text{-productivity}}{\text{productivity}}$$

Since some premium pay would be at double time, we used 60% for the maximum cost case.

For example, if the average annual productivity in the shipyard was 90% (0.90), then the maximum annual cost for regaining this lost productivity through overtime would be:

$$0.60 \times \frac{1 - 0.90}{0.90} \times \$80{,}210{,}000 = \$5{,}350{,}000.$$

Minimum Cost Case

2. If the productivity deficit is made up with an increased work force, then the annual increased cost for straight time pay only would be, using the preceding example:

$$0.374 \times \frac{1\text{-productivity}}{\text{productivity}} \times \$80{,}210{,}000 = \$3{,}330{,}000.$$

Intermediate Cost Case

3. If the productivity deficit results in a longer schedule (reduced capacity), then the annual increased cost would be:

a) $.084 \times \frac{\text{1-productivity}}{\text{productivity}}$ (Fixed Cost)

b) $.90 \times \frac{4}{12} \times 0.12 \times \frac{\text{(1-productivity)}}{\text{productivity}} = .036 \times \frac{1 - p}{p}$ (Interest on Working Capital)

assuming 90% of the costs are committed for four less months at 12% interest on working capital.

c) $.374 \times \frac{1 - p}{p}$ (Straight Time Labor Cost)

d) total = (.084 + .036 + .374) or $0.492 \times \frac{1 - p}{p}$

and the total dollar cost using the preceding examples would be:

$0.492 \times \frac{1 - 0.9}{0.9} \times \$80,210,000 = \$4,390,000$

APPENDIX L

LISTING OF THE COMPUTER PROGRAM FOR THE SHIPYARD PRODUCTIVITY MODEL

APPENDIX L

COMPUTER PROGRAM FOR THE SHIPYARD PRODUCTIVITY MODEL

The Program is Written in Fortran V for the UNIVAC 1108.

DEFINITION OF VARIABLES USED IN COMPUTER PROGRAM

PRODET	RELATIVE PRODUCTIVITY FOR EFFECTIVE TEMPERATURE CATEGORIES
PRODAT	RELATIVE PRODUCTIVITY FOR DRY BULB TEMPERATURE CATEGORIES
PRODWS	RELATIVE PRODUCTIVITY FOR WIND CATEGORIES
PRODPR	RELATIVE PRODUCTIVITY FOR PRECIPITATION CAGETORIES
FGP	RELATIVE PRODUCTIVITY FOR FOG CATEGORIES
PRODSH	RELATIVE PRODUCTIVITY FOR SHADE CATEGORIES
RTTIO	RATIO CRAFTSMEN AT OTHER LOCATIONS TO OUTSIDE CRAFTSMEN OR SHOP CRAFTSMEN TO IN-SHIP CRAFTSMEN
RAINPR	FRACTION SHIFT WORKED DURING PRECIPITATION PERIODS
NAM	SHIPYARD LOCATION
DT	DRY BULB TEMPERATURE CATEGORIES
ET	EFFECTIVE TEMPERATURE CATEGORIES
WIND	WIND VELOCITY CATEGORIES
SUN	FRACTION OF SHIFT WITH SUNSHINE
FOG	FRACTION OF SHIFT WITH FOG
PREC	PRECIPITATION CATEGORIES
RH	RELATIVE HUMIDITY CATEGORIES
PT	CORRECTION OF EFFECTIVE TEMPERATURE FOR PAINTERS
EPROD	AVERAGE ANNUAL PRODUCTIVITY FOR EFFECTIVE TEMPERATURE CATEGORIES
APROD	AVERAGE ANNUAL PRODUCTIVITY FOR DRY BULB TEMPERATURE CATEGORIES
WPROD	AVERAGE ANNUAL PRODUCTIVITY FOR WIND CONDITIONS
PRPROD	AVERAGE ANNUAL PRODUCTIVITY FOR PRECIPITATION (RELATIVE HUMIDITY FOR PAINTERS) CONDITIONS
FOGPR	AVERAGE ANNUAL PRODUCTIVITY FOR FOG CONDITIONS
SUNPR	AVERAGE ANNUAL PRODUCTIVITY FOR SUN CONDITIONS
GW	IDEAL WEATHER OUTSIDE
AGW	IDEAL WEATHER IN-SHIP
BGW	EXCESS IDEAL WEATHER IN-SHIP OVER OUTSIDE
TPROD	TOTAL ANNUAL PRODUCTIVITY FOR EACH TEMPERATURE CATEGORY
PCT	DISTRIBUTION OF WORKMEN BETWEEN SHIFTS
ICRAFT	NUMBER OF WORKMEN OF EACH CRAFT AT EACH LOCATION
JCRAFT	NUMBER OF WORKMEN OF EACH CRAFT AT EACH LOCATION ON EACH SHIFT
LCRAFT	FRACTION OF TOTAL WORKMEN ON EACH SHIFT AND LOCATION
ADDER	INCREASE IN PRODUCTIVITY ACHIEVABLE THROUGH TRANSFER OF CRAFTSMEN TO OUTSIDE WORK DURING IDEAL WEATHER
SADDER	INCREASE IN PRODUCTIVITY ACHIEVABLE THROUGH TRANSFER OF SHOP CRAFTSMEN TO IN-SHIP WORK DURING IN-SHIP IDEAL WEATHER (SEE DEFINITION FOR BGW)
SPRD	AVERAGE SHIFT PRODUCTIVITY
TPRD	AVERAGE CRAFT PRODUCTIVITY

APPENDIX L (contd)

YARD	AVERAGE PRODUCTIVITY AT EACH WORK LOCATION
YARDT	AVERAGE ANNUAL SHIPYARD PRODUCTIVITY
TOPAY ZPAY TTPAY YDPAY	VARIABLES ORIGINALLY USED FOR ANNUAL WAGE PAYMENT CALCULATIONS RELATED TO TRANSFER AND PASS OUT CONDITIONS. THIS PART OF THE PROGRAM WAS DISCARDED WHEN THE VARIATION ~~IN~~ WAGE PAYMENTS WAS FOUND TO BE INSIGNIFICANT

LISTING OF THE COMPUTER PROGRAM FOR THE SHIPYARD PRODUCTIVITY MODEL

```
'IT FR5 SHIPS,SHIPS
      DIMENSION PRODET(5,8),PRODAT(5,8),RTTIO(5,3),
     1PRODWS(2,5,3),PRODPR(2,5,4),FGP(5),
     2PRODSH(2),RAINPP(4),NAM(8),DT(3,8),ET(3,8),WIND(3,3),SUN(3),
     3PREC(3,4),RH(3,2),PT(3,4),EPROD(5,3,8),APROD(5,3,8),WPROD(2,5,3),
     4PRPROD(2,5,3),FOGPR(5),SUNPR(2,3),GW(3,5),AGW(3,5),BGW(3,5),
     5TPROD(3,5,3,8),PCT(3),ICRAFT(5,3),JCRAFT(5,3,3),DCRAFT(5,3,3),
     6ADDER(3,5),SADDER(3,5),SPRD(3,5,3),TPRD(3,5),YARD(3),TOPAY(3,5,3)
     7,ZPAY(4,5),TTPAY(3,5),YDPAY(3)
      SUN(3)=0.0
      DATA((PRODET(I,J),J=1,8) ,I=1,5) / .3,.56,.75,.92,1.,.84,.48,.15,.
     125,.51,.7,.92,1.,.79,.48,.15,.25,.56,.75,.92,1.,.84,.53,.20,.25,.5
     31,.70,.92,1.,.84,.53,.2,.3,.56,.75,.92,1.,.84,.53,.2/
      DATA((PRODAT(I,J),J=1,8),I=1,5) /3*0.,.7,1.,.79,.48,.15,.3,.56,.75
     1,2*1.,.74,.43,.1,.3,.56,.75,.9,1.,.79,.48,.15,.3,.56,.75,.92,1.,.7
     39,.48,.15,.3,.56,.75,.92,1.,.79,.48,.15/
      DATA PRODWS /10*1.,.7,1.,.8,1.,.9,1.,.9,1.,.95,1.,0.,.8,.1,.8,.15,
     1.8,.2,.8,.4,.8/
      DATA PRODPR /10*1.,2*0.,.8,1.,.95,1.,.95,1.,.95,1.,3*0.,.95,.85,.9
     15,.85,.95,.9,.95,3*0.,.8,.4,.8,.4,.8,.5,.8/
      DATA (FGP(J),J=1,5) /2*1.,2*.5,1./
      DATA (PRODSH(L),L=1,2) /.7,.95/
      DATA(RAINPR(I),I=1,4) / 1.0,1.0,.875,.875 /
  205 FORMAT (16F5.0)
  206 FORMAT (12F10.3)
  200 FORMAT (8A6,32X)
    3 READ 200,(NAM(I),I=1,8)
      PRINT 200, (NAM(I),I=1,8)
      IL=-1
      DO 20 I=1,3
      READ 205,(DT(I,J),J=1,8)
      IF (DT (I,5) .LT ..001) GO TO 999
      PRINT 206,(DT(I,J),J=1,8)
      READ  205,(ET(I,J),J=1,8)
      PRINT 206,(ET(I,J),J=1,8)
      READ  205, ((WIND(I,J),J=1,3),(PREC(I,J),J=1,4),(RH(I,J),J=1,2))
      PRINT 206, ((WIND(I,J),J=1,3),(PREC(I,J),J=1,4),(RH(I,J),J=1,2))
      READ  205,(PT(I,J),J=1,4)
      PRINT 206,(PT(I,J),J=1,4)
      IF (I.GT.1) GO TO 20
      READ 205, SUN(1),SUN(2),FOG
      PRINT 206, SUN(1),SUN(2),FOG
   20 CONTINUE
   21 CONTINUE
      IF(IL.GE.0) PRINT 847
  847 FORMAT ('  THIS MODEL DOES NOT PERMIT TRANSFER BETWEEN LOCATIONS')
C     TEMPERATURE PRODUCTIVITY CALCULATIONS
      DO 52 L=1,2
      DO 50 J=1,5
```

```
      DO 40 K=1,3
      WPROD(L,J,K)=0.
      PRPROD(L,J,K)=0.
      CHECK=RH(K,1)+RH(K,2)
      IF (CHECK.GT.1.01.OR.CHECK.LT..99)PRINT 803,K,K,K
      CHECK=0.
      CHECL=0.
      DO 30 I=1,8
      PC =0.
      CHECK=CHECK+ET(K,I)
      CHECL=CHECL+DT(K,I)
      IF(J.EQ.1.AND.I.LE.4)PC=PT(K,I)
      EPROD(J,K,I)=PRODET(J,I)*(ET(K,I)-PC)
      APROD(J,K,I)=PRODAT(J,I)*DT(K,I)
   30 CONTINUE
  210 FORMAT (3I5,2F10.3)
      IF (CHECK.GT.1.01.OR.CHECK.LT..99)PRINT 803,L,J,K
      IF (CHECL.GT.1.01.OR.CHECL.LT..99)PRINT 803,L,J,K
  803 FORMAT ('  ERROR IN SUM CHECK' 3I5)
      CHECK=0.
      CHECL=0.
C     WIND PRODUCTIVITY CALCULATIONS
      DO 35 I=1,3
      CHECK=CHECK+WIND(K,I)
   35 WPROD(L,J,K)=WPROD(L,J,K)+(PRODWS(L,J,I)*WIND(K,I))
      IF (CHECK.GT.1.01.OR.CHECK.LT..99)PRINT 803,L,J,K
C     PRECIPITATION AND HUMIDITY PRODUCTIVITY CALCULATIONS
      IF (J.EQ.1) GO TO 41
      DO 36 I=1,4
      CHECL=CHECL+PREC(K,I)
      IF (PRODPR(L,J,I).EQ..0) GO TO 37
      PRPROD(L,J,K)=PRPROD(L,J,K)+PREC(K,I)*PRODPR(L,J,I)*RAINPR(I)
      GO TO 39
   37 PRPROD(L,J,K)=PRPROD(L,J,K)+PREC(K,I)*.075
   39 CONTINUE
   36 CONTINUE
      IF (CHECL.GT.1.01.OR.CHECL.LT..99)PRINT 803,L,J,K
      GO TO 42
   41 PRPROD(L,J,K)=PRPROD(L,J,K)+(1.*RH(K,1)+RH(K,2)*.075)
   42 CONTINUE
C     IDEAL WEATHER OUTSIDE
      GW(K,J)=ET(K,5)*WIND(K,1)*PREC(K,1)
      IF (J.EQ.1)GW(K,J)=GW(K,J)*RH(K,1)/PREC(K,1)
      IF (J.EQ.3.OR.J.EQ.4) GW(K,J)=GW(K,J)*(1-FOG)
C     FOG AND SHADE EFFECTS
      SUNPR(L,K)=1.00*(1-SUN(K))+PRODSH(L)*SUN(K)
C     IDEAL WEATHER IN SHIP
      AGW(K,J)=DT(K,5)*(WIND(K,1)+WIND(K,2))*(PREC(K,1)+PREC(K,2))
      IF (J.EQ.1) AGW(K,J)=AGW(K,J)*RH(K,1)/(PREC(K,1)+PREC(K,2))
      IF (J.EQ.3.OR.J.EQ.4) AGW(K,J)=AGW(K,J)*(1-FOG)
```

```
      AGW(K,J)=AGW(K,J)-GW(K,J)
   40 CONTINUE
      FOGPR(J)=1.00*(1-FOG)+FGP(J)*FOG
   50 CONTINUE
   52 CONTINUE
C     TOTAL PRODUCTIVITY CALCULATIONS
      DATA (PCT (K) , K = 1,3) / . 65, . 30, . 05/
      KTOTAL = 2038
      DATA ((ICRAFT (J,L), J = 1,5), L = 1,3) / 60, 227,
     161, 237, 57, 39, 272, 58, 229, 308, 7, 156,
     243, 204, 80/
      DO 90 L = 1,3
      DO 90 J = 1,5
      ZPAY(L,J)=0.
      TPRD(L,J)=0.
      DO 90 K = 1,3
      DO 89 I=1,8
      SC=1.
      IF (I.GE.6) SC=SUNPR(L,K)
      IF  (L.EQ.2) GO TO 80
      IF (L.EQ.3) GO TO 82
C     OUTSIDE PRODUCTIVITY
      TPROD (L,J,K,I) = EPROD (J,K,I ) * WPROD (L,J,K) * PRPROD (L,J,K)
     1*FOGPR(J)*SC
      GO TO 88
C     INSIDE PRODUCTIVITY
   80 CONTINUE
      TPROD (L,J,K,I) = APROD (J,K,I) * WPROD (L,J,K) * PRPROD (L,J,K) *
     1FOGPR(J)*SC
      GO TO 88
   82 TPROD (L,J,K,I)=1.*DT(K,I)
   88 CONTINUE
      CTOT=CTOT+TPROD(L,J,K,I)
   89 CONTINUE
      PRINT 12,CTOT,L,J,K
      CTOT=0.
   12 FORMAT (' TOTAL PRODUCTIVITY IS'F7.3,' AT LOCATION'I3,' FOR CRAFT'
     1I3,' AND SHIFT'I3)
C     DISTRIBUTION OF WORKERS
      JCRAFT (J,L,K) = ICRAFT (J,L)  * PCT (K) + .5
      DCRAFT (J,L,K) =FLOAT( JCRAFT (J,L,K))/ FLOAT(KTOTAL)
   90 CONTINUE
C     IDEAL WEATHER ADDER
      DO 111 J = 1,5
      RTTIO (J,2) =FLOAT(ICRAFT(J,3))/FLOAT(ICRAFT(J,2) )
  111 RTTIO (J,1) =FLOAT(I CRAFT (J, 2) + I CRAFT (J,3))/ FLOAT(ICRAFT (
     1J,1))
      YARDT=0.
      DO 188 LY= 1,3
      L=LY
```

```
      YARD(L)=0.
      YDPAY(L)=0.
      DO 187 J = 1,5
      TTPAY(L,J)=0.
      DO 186 K = 1,3
      SPRD(L,J,K)=0.
      IF (L.GE.2) GO TO 183
C   THIS STATEMENT PROHIBITS TRANSFERS BETWEEN LOCATIONS
      IF(IL.GE.0) GO TO 183
      DO 128 I=1,8
      IF (J.GT.1) GO TO 127
      PAINT = RH (K,2) *(.7*(ICRAFT(J,1)+ICRAFT(J,2)))/ICRAFT(J,3)
      TPROD (3,1,K,I) = TPROD (3,1,K,I)*(1+ PAINT        )
  127 CONTINUE
      IF (J.NE.2) GO TO 128
      WELD = (PREC(K,3) + PREC(K,4))*(.7*ICRAFT(J,1))/ICRAFT(J,2)
      TPROD (2,2,K,I) = TPROD (2,2,K,I)*(1+WELD)
  128 CONTINUE
      ADDER (K, J) = GW (K, J) * (RTTIO (J,1))
      TPROD (1,J,K,5) = TPROD (1,J,K,5)   +ADDER (K,J)
      TPROD (2,J,K,5) = TPROD (2,J,K,5)-GW(K,J)
      TPROD (3,J,K,5) = TPROD (3,J,K,5)-GW(K,J)
C     IN SHIP ADDER
      SADDER (K,J) = BGW (K,J) * (  RTTIO (J,2))
      TPROD (2,J,K,5) = TPROD (2,J,K,5) + SADDER (K,J)
      TPROD (3,J,K,5) = TPROD (3,J,K,5) - BGW (K,J)
  183 CONTINUE
      DO 185 I = 1,8
  185 SPRD (L,J,K) = SPRD (L,J,K) + TPROD (L,J,K,I)
      PRINT 313, L, J, K, SPRD (L,J,K)
  313 FORMAT ( ' TOTAL SHIFT PRODUCTIVITY' 3I5, F 10.3)
  186 TPRD (L,J) = TPRD (L,J) + SPRD (L,J,K)*PCT(K)
      IF (TPRD(L,J).GT.1) GO TO 273
      GO TO 274
  273 XY=TPRD(L,J)-1.
      ZPAY(L,J)=ZPAY(L,J)-XY
      LL=L+1
      IF (LL.EQ.4) LL=1
      IF (TPRD(LL,J).EQ.1.) LL=LL+1
      PY=(XY*ICRAFT(J,L))/ICRAFT(J,LL)
      ZPAY(LL,J)=ZPAY(LL,J)+PY
      TPRD(L,J)=1.
      TPRD(LL,J)=TPRD(LL,J)+PY
      PRINT 917,XY,L,LL,PY
  917 FORMAT (F7.3,'EXCESS PRODUCTIVITY TRANSFERRED FROM LOCATION'I3,'
     1EQUIVALENT PRODUCTIVITY GAIN AT'I3,' IS'F7.3)
      IF (TPRD(LL,J).LE.1.) GO TO 274
      XY=TPRD(LL,J)-1.
      ZPAY(LL,J)=ZPAY(LL,J)-XY
```

```
      TPRD(LL,J)=1.
      LQ=LL+1
      IF (LQ.EQ.4) LQ=1
      PY=(XY*ICRAFT(J,LL))/ICRAFT(J,LQ)
      TPRD(LQ,J)=TPRD(LQ,J)+PY
      ZPAY(LQ,J)=ZPAY(LQ,J)+PY
      PRINT 917,XY,LL,LQ,PY
  274 CONTINUE
      PRINT 314, L, J, TPRD (L,J)
  314 FORMAT (' CRAFT PRODUCTIVITY' 2I5 , F10.3)
  187 YARD (L) = YARD (L) +(TPRD (L,J) *ICRAFT(J,L))/KTOTAL
      PRINT 315, L, YARD (L)
  315 FORMAT (/' LOCATION' I5, F10.3)
  188 YARDT = YARDT + YARD (L)
      PRINT 316, YARDT, (NAM (I), I = 1,8)
  316 FORMAT (/' YARD PRODUCTIVITY', F 10.3, 5X, 8A6)
      BX=1.-YARDT
      CX=BX/YARDT
      DX=.374*CX
      PRINT 319,DX
  319 FORMAT ('  EXCESS STRAIGHT TIME LABOR COST',F6.3)
      IL=IL+1
      IF (IL.GE.7) GO TO 599
      IF(IL.EQ.0) GO TO 21
      GO TO (591,593,594,592,601,611),IL
  591 PRODSH(1)=1.
      PRODSH(2)=1.
      PRINT 595
  595 FORMAT (' PRODUCTIVITY WITH SHADE PROVIDED')
      GO TO 21
  592 DO 757 L=1,2
      DO 757 J=1,5
      DO 757 K=1,3
      PRODWS(L,J,K)=1.
  757 CONTINUE
      PRODET(1,1)=0.
      PRODET(1,2)=0.
      PRODET(1,3)=0.
      PRODET(1,4)=.7
      DO 609 K=1,3
      DO 609 I=1,8
      IF (I.LE.4) PT(K,I)=0.
  609 ET(K,I)=DT(K,I)
      PRINT 596
  596 FORMAT ('  PRODUCTIVITY WITH WIND PROTECTION')
      GO TO 21
  593 DO 758 L=1,2
      DO 758 J=1,5
      DO 758 K=1,4
```

```
      PRODPR(L,J,K)=1.
  758 CONTINUE
      RAINPR(3)=1.
      RAINPR(4)=1.
      PRINT 597
  597 FORMAT ('  PRODUCTIVITY WITH RAIN PROTECTION')
      GO TO 21
  594 CONTINUE
      DO 602 K=1,3
      RH(K,1)=1.
  602 RH(K,2)=0.
      PRINT 598
  598 FORMAT ('  PRODUCTIVITY WITH DEHUMIDIFIERS')
      GO TO 21
  601 DO 604 J=1,5
      DO 604 I=6,8
      PRODET(J,I)=1.
  604 PRODAT (J,I)=1.
      PRINT 606
  606 FORMAT ('  PRODUCTIVITY WITH COOLING PROVIDED')
      GO TO 21
  611 DO 613 J=1,5
      DO 613 I=1,4
      PRODET(J,I)=1.
      PRODAT(J,I)=1.
  613 CONTINUE
      PRINT 615
  615 FORMAT ('  PRODUCTIVITY WITH HEATING PROVIDED')
      GO TO 21
  599 CONTINUE
      GO TO 3
  999 CONTINUE
      STOP
      END
' XQT SHIPS
      SAN DIEGO
   .0    .0    .0 .001 .963 .033 .003    .0
   .0    .0    .0 .018 .946 .033 .003    .0
.8638.1350.0025 .983 .006 .007 .004.9862.0138
   .0    .0    .0   .0
.6765.2750   .01
   .0    .0    .0   .0 .986 .013   .0    .0
   .0    .0    .0 .016 .971 .013   .0    .0
.9638.0350.0013 .981 .006 .010 .003.9512.0488
   .0    .0    .0   .0
   .0    .0    .0   .0 .991 .008   .0    .0
   .0    .0 .001 .018 .973 .008   .0    .0
.9800.0200.0013 .975 .009 .013 .003.8275.1725
   .0    .0    .0   .0
```

```
' XQT SHIPS
      PHILADELPHIA
   .0 .021 .070 .167 .629 .097 .017 .000
 .019 .105 .144 .150 .473 .093 .016 .000
.6188.3613.0175 .935 .018 .036 .011.9062.0938
 .019 .079 .052 .012
.4275.1925  .01
   .0 .017 .064 .172 .659 .077 .011    .0
 .016 .096 .150 .158 .493 .077 .011    .0
.7425.2475.0100 .929 .020 .037 .014.8800.1200
 .016 .073 .055 .015
   .0 .013 .048 .171 .719 .046 .004    .0
 .011 .071 .145 .158 .555 .046 .004    .0
.8188.1788.0063 .923 .020 .039 .018.7137.2863
 .011 .050 .053 .019
```

END

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